4366

A 13

STATUS REVIEW OF COHO SALMON POPULATIONS IN SCOTT AND WADDELL CREEKS, SANTA CRUZ COUNTY, CALIFORNIA

BY

Gregory J. Bryant

National Marine Fisheries Service

Southwest Region

Protected Species Management Division

777 Sonoma Avenue, Room 325

Santa Rosa, California 95404

April 1994

STATUS REVIEW OF COHO SALMON IN SCOTT CREEK AND WADDELL CREEK; SANTA CRUZ COUNTY, CALIFORNIA

BY

Gregory J. Bryant

DRAFT

National Marine Fisheries Service

Southwest Fisheries Region

Protected Species Management Division

777 Sonoma Avenue, Room 325

Santa Rosa, California 95404

April

~~February~~ 1994

CONTENTS

(continued Table of Contents)

SUMMARY

This report summarizes biological information gathered in conjunction with an Endangered Species Act (ESA) status review for coho salmon (Oncorhynchus kisutch) from Scott Creek and Waddell Creek in Santa Cruz County, California. The National Marine Fisheries Service (NMFS) received a petition in March 1993 asking that the coho populations of Scott and Waddell Creeks be listed as an endangered species. In evaluating the petition, two key questions had to be addressed: Do Scott Creek and Waddell Creek coho salmon represent a species as defined by the ESA? And if so, is the species threatened or endangered? With respect to the first question, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. NMFS policy on this issue for Pacific salmon is that a population will be considered "distinct" for the purposes of the ESA if it represents an evolutionary significant unit (ESU) of the species as a whole. To be considered an ESU, a population or group of populations must 1) be substantially reproductively isolated from other populations, and 2) contribute substantially to ecological/genetic diversity of the biological species. Once an ESU is identified, a variety of factors related to population abundance and factors affecting its continued existence are considered in determining whether a listing is warranted.

The petitioners argued that Scott and Waddell Creeks represent the last streams south of San Francisco Bay to support

coho populations, and geographic isolation (greater than 50 miles) from coho streams north of San Francisco Bay qualifies the coho populations of Scott and Waddell Creeks as an ESU. Distinctive life history and habitat characteristics were the primary factors identified by the petitioners as evidence that Scott and Waddell Creeks contribute substantially to the species ecological/genetic diversity. The petitioners also stated that several factors have lead to the decline of coho salmon in Scott and Waddell Creeks including: habitat degradation, over-exploitation, disease, stream dewatering, poaching, lagoon constrictions, in-river competition with other fish species, and excessive predation by marine mammals. Furthermore, the petitioners stated that Scott and Waddell Creeks have a 90 percent reduction of their average runs of 50 years ago, and declines of 95 percent to 98 percent from estimated runs in the 1800's, which was evidence to the petitioners that the populations qualified for listing under the ESA.

In evaluating the status of Scott and Waddell Creek's coho salmon, NMFS focused on information for coho salmon populations from the central and northern California coasts. NMFS concluded that the available information does not make a strong case for reproductive isolation of Scott and Waddell Creek's coho salmon populations. Genetic data gathered for this status review fail to show that Scott Creek and Waddell Creek coho salmon as a group are distinct from other coastal coho populations. Although this does not prove that Scott Creek and Waddell Creek coho salmon are not reproductively isolated, it does mean that evidence to support reproductive isolation must be found elsewhere. Currently, NMFS is conducting a coastwide status review of coho salmon populations in California, Oregon, Washington, and Idaho which may establish the degree of stock differentiation that now exists throughout Pacific coast watersheds.

ACKNOWLEDGMENTS

The status review for Scott and Waddell Creek's coho salmon was conducted by the NMFS Southwest Region. The biological review relied on an extensive ESA public record developed pursuant to this review, and was comprised of public comments and research reports submitted by dedicated public, state, and federal agencies. Special acknowledgement should be extended to Gareth Penn of the National Oceanic and Atmospheric Administration (NOAA) and Jeff Spencer of the California Department of Fish and Game (CDFG) who bore the burden of supplying the majority of publications required for this status review.

NMFS would also like to acknowledge the assistance of personnel from CDFG including Steve Taylor of Inland Fish and Game in Sacramento, Jennifer Nelson and Keith Anderson of Region 3 in Monterey for supplying current reports and local biological information, and CDFG fish pathologist Dr. Bill Cox for supplying fish disease information related to central coast salmonid stocks. NMFS also acknowledges the assistance of Jennifer Nielsen from the U.S. Forest Service, Dr. Dougald Scott from Cabrillo College, Dr. Graham Gall from the University of California Davis for supplying information and reports on California salmonid genetics, Dr. Peter Moyle from the University of California Davis for supplying information he had collected on coho stocks in California, Dr. Jerry Smith from San Jose State

University for supplying information and reports he had conducted on salmon and steelhead within central California coast streams. Special thanks to Dave Streig of the Monterey Bay Salmon and Trout Project (MBSTP) and Dave Hope of the Santa Cruz County Planning Department for supplying information and a great deal of knowledge of the local salmonid fisheries and watersheds. Finally, we would like to acknowledge personnel from the NWFSC including Robin Waples, George Milner, Tom Wainwright, and Laurie Weitkamp, and Chris Mobley from the SW Region for their assistance in reviewing this manuscript.

INTRODUCTION

Coho salmon (Oncorhynchus kisutch) are anadromous along the Pacific coast from Chamalu Bay, Mexico (Miller and Lea 1972), to Point Hope, Alaska, through the Aleutians, and from the Anadyr River, USSR, south to Hokkaido, Japan (Scott and Crossman 1973).

In California, coho salmon historically used most of the accessible coastal streams from Monterey County north to the Oregon border (Hassler et al. 1991). However, coho salmon no longer occur in many streams and their numbers are greatly reduced in others (Brown and Moyle 1991). The California Advisory Committee on Salmon and Steelhead Trout (1988) found that coho salmon run sizes have decreased by 80% to 90% from the 1940's. Moyle et al. (1989) listed coho salmon as a species of special concern in California. They classified coho salmon as a Class 3 species, meaning that it is currently an uncommon species throughout much of its natural range, but formally more abundant, with pockets of abundance within its range. The American Fisheries Society listed 214 native naturally spawning stocks of anadromous salmonids that are declining, and rated their risk of extinction in the near future (Nehlsen et al. 1991). California coho salmon populations south of San Francisco Bay were rated at a high risk of extinction. Currently all streams south of San Francisco Bay have lost their natural spawning populations of coho salmon, except Scott and Waddell Creeks in Santa Cruz County (Brown and Moyle 1991, Marston 1992, Smith 1992, Nelson 1993).

In response to indications that the populations within Scott and Waddell Creeks are declining, the Santa Cruz County Fish and Game Advisory Commission conducted a year of investigations and three local public hearings. At the request of the Santa Cruz County Fish and Game Advisory Commission, the Santa Cruz County Planning Department prepared and on March 11, 1993 submitted a petition to the National Marine Fisheries Service (NMFS) to list the coho salmon populations of Scott Creek and Waddell Creek as endangered (Santa Cruz County Planning Department 1993) under the U.S. Endangered Species Act (ESA or Act) of 1973 as amended (U.S.C. 1531 et seq.). On 18 June 1993, NMFS published (58 FR 33605) its intent to conduct a status review of California coho salmon stocks occurring in Scott and Waddell Creeks. This report summarizes this status review of coho salmon in Scott and Waddell Creeks conducted by the NMFS Southwest Region.

KEY QUESTIONS IN ESA EVALUATIONS

Two key questions must be addressed in determining whether a listing under the ESA is warranted:

1) Is the entity in question a "species" as defined by the ESA?

2) If so, is the "species" threatened or endangered?

The "Species" Question

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the Act provides no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy (56 FR 58612) describing how the agency will apply the definition of "species" in the Act to anadromous salmonid species (NMFS 1991). The NMFS policy stipulates that a salmon population (or a group of populations) will be considered "distinct" for the purposes of the Act if it represents an evolutionarily significant unit (ESU) of the biological species (Waples 1991). An ESU is defined as a population that 1) is reproductively isolated from conspecific populations and 2) represents an important component in the evolutionary legacy of the species. Types of information that can be useful in determining the degree of reproductive isolation include incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance can be provided by data on phenotypic, protein, or DNA characters; life-history characteristics; habitat differences; and the effects of stock transfers or supplementation efforts.

Thresholds for Threatened or Endangered Status

Neither NMFS nor the U.S. Fish and Wildlife Service (USFWS), which share authority for administering the ESA, has an official policy regarding thresholds for considering ESA "species" as threatened or endangered. NMFS has published a nonpolicy document on this topic (Thompson 1991). There is considerable interest in incorporating the concepts of Population Viability Analysis (PVA) into ESA threshold considerations for Pacific salmon. However, most of the PVA models require substantial life-history information that often will not be available for Pacific salmon populations.

Therefore, NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important factors include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and current carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., from strays or outplants from hatchery programs); 6) recent events (e.g., drought) that have predictable short-term consequences for abundance of the ESU (Waples 1991).

Hatchery Fish and Natural Fish

Artificial propagation of Pacific salmonids has been widespread for many years. Hence, hatchery influences need to be considered in salmonid ESA status reviews. The ESA has as its first stated purpose "to provide a means whereby the ecosystem upon which endangered and threatened species depend may be conserved." The Department of Commerce is mandated to conserve endangered and threatened species in their natural habitats. NMFS policy stipulates that in determining whether a population is "distinct" for the purposes of the ESA, attention should be focused on "natural" fish, which are the progeny of naturally spawning fish (Waples 1991). This approach directs attention to fish that spend their entire life cycle in natural habitat and is consistent with the mandate of the ESA to conserve threatened and endangered species in their native ecosystems. Implicit in this approach is the recognition that fish hatcheries are not a substitute for natural ecosystems.

The decision to focus on natural fish is based entirely on ecosystem consideration; the question of the relative merits of hatchery versus natural fish is a separate issue. Fish are not excluded from ESA consideration simply because some of their direct ancestors may have spent time in a fish hatchery, nor does identifying a group of fish as "natural" as defined here automatically imply that they are part of an ESU.

Once the natural component of a population has been identified, the next step is to determine whether this population component is "distinct" for the purposes of the Act. In making this determination, we used guidelines in the NMFS "Definition of a Species" paper (Waples 1991). We considered factors outlined in the section entitled "Effects of artificial propagation and other human activities" to determine the extent to which artificial propagation may have affected the natural fish, through either direct supplementation or straying of hatchery fish. Therefore, fish meeting the definition of "natural" adopted here could be excluded from ESA consideration.

Threshold determinations also will focus on natural fish, on the premise that an ESU is not healthy unless a viable population exists in the natural habitat. If an existing hatchery is associated with the listed "species", an important question to address in formulating a recovery plan is whether the hatchery population is similar enough to the wild population that it can be considered part of the ESU. Factors to consider in this regard include origin of donor stock(s), evidence for domestication or artificial selection, population size, and the number of generations the stock has been cultured. In general, hatchery populations that have been substantially changed as a result of these factors should not be considered part of an ESU.

PETITION TO LIST SCOTT AND WADDELL CREEK'S COHO SALMON

This section summarizes claims made by the petitioner (Santa Cruz Planning Department 1993) to support the designation of Scott and Waddell Creek's coho salmon as an ESU, and to support the listing of that ESU under the ESA. Organization of this section, and references to the criteria of Reproductive Isolation and Evolutionary Significance, follows that of the petition. After discussing information relevant to each of these issues in the next section of this status review, we evaluate the merits of the petitioners' arguments in the Discussion and Conclusions section.

Reproductive Isolation

Geographic Isolation

Distance to nearest coho populations: The petitioner referenced Waples (1991) and Ricker (1972) and stated "because all streams south of San Francisco Bay have lost their runs of coho salmon, and the central coast coho are separated by 50 miles from any other northern California coho stream, they may be considered a genetically isolated stock of Pacific salmon" (Santa Cruz County Planning Department 1993, p.3).

Genetic Differences

North-south genetic differences: The petition cited Bartley (1987), who conducted electrophoretic analyses on several California streams and found 0.00 heterozygosity for coho salmon in Scott Creek. The petitioner stated that this genetic difference presumably reflects reproductive isolation from coho salmon populations in northern California (Santa Cruz County Planning Department 1993, p.23).

Life History Traits

Timing of peak spawning: The petitioner cited Shapovalov and Taft (1954), who indicated that in Waddell Creek, peak spawning takes place between 15 January and 15 February, and spawning migrations often do not begin until late November or December. The petitioner cited Sandercock (1991) who stated "that in Oregon streams, spawning can occur as late as March, if drought conditions delay rains or runoff." Smith (1991) was also cited as finding the same conditions on Scott and Waddell Creeks (Santa Cruz County Planning Department 1993, p.9). "The non-native hatchery coho used within Santa Cruz County were derived from stream habitats that are dissimilar from local streams (northern California, Oregon, and Washington), and differences in spawning run times, poor spawning conditions, warmer water, and high sediment loads create special conditions that require adaptations which few other anadromous fish possess (Santa Cruz County Planning Department 1993, p.5). The success of early run coho in accessing spawning grounds during the early fall period is poor due to the closure of the river mouths by sand bars (Shapovalov and Taft 1954, Smith 1990 as cited in Santa Cruz County Planning Department 1993, p.5). Survival of eggs in these early run coho spawning redds is also poor due to the disturbance of the extremely mobile bedload and high sediment input from storms that occur from December to as late as March and April" (Smith 1992 as cited in Santa Cruz County Planning Department 1993, p.5).

Evolutionary Significance

Habitat Characteristics

The petitioner stated that "central coast coho salmon survival is much more tenuous due to the extreme physical, climatic, and hydrologic factors found within the far southern end of their range" (Santa Cruz County Planning Department 1993, p.8). The petitioner felt that native central coast coho salmon populations are better adapted to survive in the unstable conditions found within the local watersheds.

Distinctive Life History Traits

Body Size at First Spawning: The petitioners stated that "there is a positive correlation between fecundity and size of female, and the average egg production of 2700 shows the smaller average size of central coast coho" (Santa Cruz County Planning Department 1993, p.9).

Effects of Hatchery Fish

The petitioners stated that "since hatchery plants from outside sources were discontinued 22 years ago, the remaining coho salmon runs on Scott and Waddell Creeks appear to be remnants of those "native" coho that could survive both the negative effects of the hatchery plantings and some minor genetic mixing from sporadic fingerling plants" (Santa Cruz County Planning Department 1993, p.7). With sporadic fingerling plants, it is unknown whether these hatchery coho survive to return and mix with the wild coho at rates high enough to influence the wild populations genetic makeup because of the reduced survival of coho transplants from foreign streams (Reisenbichler 1988 as cited in Santa Cruz County Planning Department 1993, p.5). McMahon (1983) was cited to show that hatchery reared coho smolts have not shown the same tenacity for producing adult returns as have naturally produced fish. The petitioners argued that "the poor survival rate of hatchery plants in general compared to the 5% to 30% survival rate of native coho reported by Shapovalov and Taft also supports the assertion" (Table 2 in Santa Cruz County

Planning Department 1993, p.6). The petitioners felt that the rate of gene influence by hatchery fish should not be considered adequate to remove important genetic differences between central coast coho salmon and north of San Francisco coho salmon.

Population Trends

The petitioners stated that "streams north and south of Scott and Waddell Creeks, but south of San Francisco, have lost their coho runs completely, and Scott and Waddell Creeks have lost over 90% of their average documented runs of 50 years ago." They also estimated that the coho salmon populations within Scott and Waddell Creeks have declined 95% to 98% from the historical runs of the 1800's (Santa Cruz County Planning Department 1993, p.1). The petitioners cited a recent study which reported that only 42 juvenile coho were found in Scott Creek and 19 juvenile coho were found in Waddell Creek (Smith 1992).

Factors Listed for Coho Salmon Declines

The petitioners stated that "several factors have led to the decline of coho salmon populations along the central California coastline including: over-exploitation, disease, stream dewatering, drought conditions, poaching, in-river competition with other species, lagoon constrictions, and habitat degradation in the lower reaches of Scott and Waddell Creeks" (Santa Cruz County Planning Department 1993, p.1).

Ocean Commercial and Sport Take

The petitioners stated that "ocean commercial and sport take of central California coho salmon are established from estimates of runs from Oregon, northern-California, and Sacramento River chinook salmon populations, and incidental harvesting of coho salmon from the central coast fisheries is considered problematic for the decreased runs on Scott and Waddell Creeks" (Santa Cruz County Planning Department 1993, p.1).

Predation

The petitioners stated that "80% of the adult salmon and steelhead seined at the mouth of the San Lorenzo River have shown marine mammal scrape marks." The petitioners attributed this from increased marine mammal populations along the central coast which prey on coho that are schooling at the mouths of the rivers and are unable to enter the rivers due to low flows not breaching the sandbars (Santa Cruz County Planning Department 1993, p.2).

In-Stream Competition

The petitioners stated that "in-stream competition/predation from steelhead, rainbow trout, and sculpins has increased due to the lack of flows and deep-water pool habitat in the lower river. Lack of adequate cover has also increased the predation rates on coho from raccoons, garter snakes, egrets, herons, and kingfishers" (Santa Cruz County Planning Department 1993, p.2).

Habitat Losses

The petitioners stated that "the lack of summer water due to overuse of drought-limited flow, coupled with a generalized degradation of stream habitat due to excessive bedload accumulations, has contributed to the serious decline in quality coho habitat. Due to clear-cutting and burning, there has been an elimination of large woody debris necessary for scouring deep pools and flushing sediment out of the system" (Santa Cruz County Planning Department 1993, p.1).

Lack of Adequate Habitat

The petitioners cited Waples and Teel (1990) and indicated that "the available habitat on Scott and Waddell Creeks is not adequate to produce the 4000 to 8000 juvenile coho needed to produce spawning runs of 200 to 400 adults that can sustain the populations through further stochastic events" (Santa Cruz County Planning Department 1993, p.3).

SUMMARY OF BIOLOGICAL AND ENVIRONMENTAL INFORMATION

Geographic Setting

Scott and Waddell Creeks are adjacent watersheds that flow directly into the Pacific Ocean within 7 km of one another

(Figure 1). They are located in Santa Cruz County, approximately 24 km to the north of the City of Santa Cruz, at 37° 6′ N latitude and 122° 17′ W longitude. The main stem of Scott Creek is 29 km long, has a total of 72 km of tributary length, with a watershed covering 91 km^2. The mainstem of Waddell Creek is 19 km long, has a total of 56 km of tributary length, with a watershed covering 68 km^2.

The headwaters of both creeks begin in the redwood forests of the Santa Cruz mountains at an elevation of 750 m, and terminate within drowned mouths or lagoons which are subject to tidal action when they are not closed by sandbars during the summer months (Shapovalov and Taft 1954; Smith 1990). The watersheds receive the majority of direct rainfall between October and April, with more than half of the rainfall occurring from December through February. The headwaters receive an average of 152 to 178 cm of rainfall per year, while the coastal areas average 64 to 89 cm of rainfall per year. Because of the distinct wet and dry seasons, flows range from 150 m^3/sec during the winter to summer flows of less than 0.03 m^3/sec during drought periods. Average winter storms can produce flows of 30 m^3/sec and summer flows average between 0.09 m^3/sec and 0.15 m^3/sec.

These two streams are very diverse in the types of stream habitats they exhibit. The headwater areas are characterized by broad meadows with meandering streams and incised bedrock channels with boulder cascades and waterfalls. These channels traverse mixed coniferous forests, forming large deep pools and a turbulent stream that transition into the mainstem areas.

Lower headwater areas are Rosgen A2 and A3 stream types, with the mid-sections exhibiting B1, B2, B3, B1-1 and C1 through D4 types, and the two lower sections exhibiting mostly C1, C1-1, C3, and C4 stream types (Snider 1989). Scott Creek is composed of 77% type C, 17% type B, and 6% type A channel; while Waddell Creek is composed of 52% type C, 47% type B, and 6% type A channel (Snider 1989).

The upper main stems of both creeks are characterized by wide stream channels with fewer pools, and possess gravel and cobble substrate with sand deposits in slack water areas. The riparian vegetation along the stream corridor within this area is comprised of red alder, big leaf maple, buckeye, tan oak, huckleberry, madrone, and California bay laurel. The lower reaches are low gradient sections with sand and gravel beds, with riparian vegetation consisting of alder, black cottonwood, willows, redwood, douglas fir, and California nutmeg. Shallow pools and riffles give way to long pool and glide sections leading into the lagoons. The channels upstream of the lagoons are dominated by alder and willows, while the lagoons are surrounded by grasslands and cultivated crops.

Life History

Coho salmon are native to North America and range throughout temperate waters of the northern Pacific Ocean. They are anadromous and return to spawn in natal streams beginning in early fall. In California, coho salmon spawn in coastal streams and rivers from Monterey Bay to the Smith River (Fry 1960, Berger 1982).

There are two basic life history strategies for coho salmon: short-run populations which utilize the smaller coastal streams and long-run coho that will migrate up to 240 km in fresh water to utilize tributaries of large coastal rivers (Shapovalov and Taft 1954). The streams in Monterey Bay, such as Scott and Waddell Creeks, support the southernmost populations of coho salmon and are considered short-run coho populations (Brown and Moyle 1991, Marston 1992, Nelson 1993).

Many small coastal streams in California that have short-run coho populations are closed by sand bars at their mouths during a portion of the year, and fish cannot enter the stream until the sand bar is broken by the first heavy rains (Smith 1990, Hassler 1987). In late summer and fall, coho salmon may thus concentrate in the ocean near these streams (Shapovalov and Taft 1954).

Coho Salmon begin to enter freshwater in September but usually enter from October to March, peaking in December and January (Murphy and Shapovalov 1952, Shapovalov and Taft 1954, Smith 1992, Nelson 1993). In Waddell Creek, Shapovalov and Taft (1954) reported that 33 percent of all adult coho salmon were trapped between December 31 to January 6, 81 percent were trapped during six weeks from December 10 to January 20, and 96 percent during nine weeks from December 10 through February 10. Shapovalov and Taft (1954) reported that the adult coho salmon run in Waddell Creek (December 10-February 10) occurred during the heaviest precipitation period. Shapovalov and Taft (1954) also reported that 83 percent of returning adult coho salmon passed upstream of the Benbow Dam on the south fork of the Eel River in six weeks from November 26 through January 6 (1938-1944), and 81 percent of the returning adult coho salmon passed the Sweasey Dam on the Mad River in six weeks from November 12 through December 23 (1941-1953). Shapovalov and Taft (1954) reported that coho salmon migrations started in November and continued through the beginning of March in the Eel River and the end of February in the Mad River, with peak spawning taking place in December and January in both systems.

Coho salmon spawn in riffles, usually just below a pool, at temperatures of 6 to 12 °C (Shapovalov and Taft 1954). The time required for coho salmon eggs to hatch is inversely related to water temperature. Shapovalov and Taft (1954) reported that eggs usually hatched in 35-50 days at temperatures prevailing in Waddell Creek; in hatcheries they reported hatching in about 38-48 days at average temperatures of 9 to 11 °C. In 1936, Shapovalov and Taft (1954) found that egg production for Scott and Waddell Creek's coho salmon was between 2,782-2,789 eggs per female, and reported that egg production of Scott Creek and

Waddell Creek coho salmon were within the range reported for other coho salmon populations. Coho salmon larvae start emerging from the gravel 2-3 weeks after hatching, and continue to emerge for an additional 2-7 weeks, with peak emergence occurring within three weeks of hatching (Shapovalov and Taft 1954).

Although early and late emerging populations often exist sympatrically within a stream system, proper timing of emergence has distinct survival advantages. As the fry emerge from the gravel they take up residence along the sides of the creeks and become aggressive and territorial (Chapman 1962, Mason 1966). Chapman (1962) found that prior residents are always dominant in territorial disputes, and later emerging fry are forced to establish and defend territories in vacant habitats. Many late emerging fry, finding no vacant territory, form schools of subordinate fish that survive by swamping territory holders or drifting downstream in search of vacant habitats. During July and August they move into deeper pools with overhanging vegetation and woody debris (Shapovalov and Taft 1954, Marston 1992). It appears that all coho salmon fry must find some freshwater habitat for their first year of life, because no returning adults have ever been observed without a freshwater annulus (Shapovalov and Taft 1954, Mason 1975).

Shapovalov and Taft (1954) reported that approximately one year after emergence in Scott and Waddell Creeks, usually in March and April, schools of 10-50 individuals of the same length migrated to the ocean. They reported that coho salmon average 10.3 to 11.7 cm fork length (FL) at outmigration.

Juvenile coho usually spend two growing seasons at sea before they return as adults to freshwater to spawn. In Waddell Creek, Shapovalov and Taft (1954) found that coho returned as precocious males (16% of the run) in the season after downstream migration with an average size of 40.6 cm FL (age 1.1, one growing season in freshwater and one in the ocean), or as females and males (84% of the run), with an average size of 63.9 cm and 64.7 cm FL respectively, in the second season after downstream migration (age 1.2, one growing season in freshwater and two in the ocean).

Coho salmon from different geographic regions appear to have their own oceanic migration patterns (Quinn and Tallman 1987). Coho salmon are pelagic and readily move and disperse from one marine area to another (Fraidenburg et al. 1985). Based on recoveries of marked smolts and coded-wire tags, oceanic migration patterns of adult coho salmon along the North American Pacific coast indicate that coho salmon remain closer to their river of origin than do chinook salmon, but may travel several hundred kilometers (Wright 1968). For example, marked coho salmon from Waddell Creek were caught in the Noyo River, in Fort Bragg, California, 322 km to the north (Taft 1937), and near the San Lorenzo River in Santa Cruz County, 24 km to the south (Shapovalov and Taft 1954). Laufle et al. (1986) reported coho salmon being captured as far as 1,930 km from their point of origin. Coho salmon along the California coast probably remain within the limits of the Continental Shelf or within 160 km from shore (Shapovalov and Taft 1954).

A major factor in population cohesiveness is the fidelity with which adult salmon are able to home to their natal streams. Although ocean homing mechanisms are poorly understood, it is believed that high seas navigation is innately controlled and that the role of extrinsic environmental factors increases in importance as the salmon approach their natal estuary (Hasler and Wisby 1951; Brannon 1981; Hasler and Scholz 1983). Nearshore migration may be enhanced by onshore winds that concentrate river water close to shore, where olfactory cues further guide the salmon (Banks 1969).

Straying in coho salmon is well documented when access to natal streams is obstructed (Martin 1984). Quinn and Tallman (1987) evaluated the reported homing and straying of coho salmon from California to British Columbia, and found that homing under normal conditions was fairly accurate, ranging between 73 to 100%. Shapovalov and Taft (1954) studied the extent of homing and straying of coho salmon between Scott and Waddell Creeks, which are 7 Km apart. They found that for six seasons of marking (1933-34 through 1938-39), and the seven seasons for which returns were possible (1934-35 through 1940-41), that 85% of the fish marked at Waddell Creek returned there and 15% strayed to Scott Creek. Of the coho marked at Scott Creek, 73% returned there and 27% strayed to Waddell Creek.

HISTORY OF HATCHERY STOCKS AND OUTPLANTINGS

One of the major issues NMFS considered in determining whether a coho salmon ESU remains in Scott and Waddell Creeks, is the extent of hatchery programs in Santa Cruz County. NMFS considered three major issues: 1) history and numbers of hatchery releases, 2) composition of hatchery stocks used, and 3) geographic areas of hatchery releases. The following information is a chronological history of the egg taking and fish planting activities that occurred in Santa Cruz County, with an emphasis on Scott and Waddell Creeks compiled by the Monterey Bay Salmon and Trout Project (MBSTP) and NMFS from limited stocking and trapping records.

In 1904 the Brookdale Hatchery (San Lorenzo River) and Scott Creek Egg Taking Station were built by the City of Santa Cruz and began operation in 1905 to produce one and a half million steelhead and coho fry per year. CDFG took over the operation through a lease from the County in 1912 for a steelhead egg source. During a drought in the 1920's a new site was selected for a hatchery on Big Creek (tributary to Scott Creek), and in 1926 Big Creek Hatchery was built and began operation in 1927. The three facilities operated until the flood of 1940 damaged both Big Creek Hatchery and Scott Creek Egg Taking Station which were subsequently shut down. The Brookdale Hatchery continued operation with surplus eggs from other northern CDFG hatcheries to produce salmonid fry for planting in local streams in July or

August; however, it could not produce sufficient numbers of yearlings and was shut down in 1953. After this closure, fish planted in Santa Cruz County streams came from various Fish and Game hatcheries in northern California.

Of the few remaining original fish planting records within Santa Cruz County, CDFG biennial report data indicate the total per county and occasionally watershed (Table 1). For 15 years, between 1909 to 1941, a total of 1,907,153 coho salmon from various Pacific Coast watersheds were known to have been planted in Santa Cruz County streams. These stocking reports indicated that between 1915-1939 Scott Creek was stocked with a total of 387,413 coho salmon fry and over 10,000 coho salmon juveniles between 1967-1968. Waddell Creek was stocked with approximate total of 116,000 coho salmon fry between 1913-1933, over 10,000 coho salmon juveniles from CDFG Darrah Springs Hatchery in 1966, and an unknown number of coho salmon in 1970 (Noyo River stock) and in 1972 (Trinity River stock) by CDFG. The San Lorenzo River was stocked with a total of 577,440 coho salmon fry between 1915-1941, and an unknown number of coho salmon juveniles and fry from 1957 to present.

When the Scott Creek egg taking station was established, the policy was to spawn every female steelhead and coho salmon to try and produce 3 million eggs/year for each species (Streig 1991). Streig (1991) tabulated and reported the fry production year (fish spawned from the previous November through the end of the run that year), and the total number of green eggs taken.

Quantitative records of adult fish numbers returning to Scott Creek were not found. Using the average number of eggs per female (coho averaged 2,700 eggs and steelhead averaged 5,000 eggs) and the average sex ratio (1:1 male/female) reported by Shapovalov and Taft (1954), the approximate number of females spawned and the total number of adults spawned were estimated (Table 2).

In 1969 the Fish and Game Commission held a hearing and authorized the CDFG to issue an experimental commercial aquaculture permit to Pacific Marine Enterprises, now known as SilverKing Oceanic Farms (SKOF), to raise anadromous salmon and steelhead for release and later recapture in the lagoon of Waddell Creek (Reavis 1985). Soon after the operation began, a flood damaged the facility, and in 1979 SKOF began operation of a new facility on Davenport Landing Creek in Santa Cruz. They were unable to obtain any local California salmon stocks. Therefore, their egg sources came from other commercial or surplus from northern California and out of state stocks of Oregon, Washington, British Columbia, and Alaska (Reavis 1985, Streig 1991). Returning adult steelhead, coho, and chinook salmon to Davenport Landing Creek were hauled to a hatchery facility operated on Bean Creek near Scotts Valley in Santa Cruz (Reavis 1985). The fish were spawned at the Bean Creek facility and the smolts were returned to Davenport Landing Creek for release to the ocean. The fish traps were operated from August through June of the following year.

There were no records found for the number of fish captured, spawned, or juveniles released by SKOF during the 1970's in Waddell Creek. However, there were records found for the operations in Davenport Landing Creek during the 1980's using a variety of other river systems coho salmon stocks and are summerized in table 3 (Reavis 1985). From 1980-1984 spawning season, SKOF had a total return of 3,201 coho salmon with an average annual return of 640 coho salmon to the Davenport Landing Creek facility. During the 1980 through 1984 time period, SKOF released 949,768 coho salmon from their Davenport Landing Creek facility with an average annual stocking rate of 189,954 fish. From 1984-1988 spawning season, SKOF had a total return of 1,331 coho salmon with an average annual return of 333 coho salmon. During 1984 through 1988 time period, SKOF released 177,920 coho salmon from their Davenport Landing Creek facility, with an average annual release of 44,480 juvenile coho salmon. Approximately 85 percent of the coho salmon trapped by SKOF in their Davenport Landing Creek facility were caught in September and October each year, primaily due to artificial pumping of freshwater through Davenport Landing Creek (Reavis 1985).

In 1976 the Monterey Bay Salmon and Trout Project (MBSTP) was started, in joint venture with CDFG, to try and rebuild the declining salmonid populations in local streams. From 1976 through 1979 CDFG cage-reared salmonid stocks from their Mad River Fish Hatchery (Humboldt County) and Warm Springs Fish Hatchery (Sonoma County) near Moss Landing in Santa Cruz. The

Big Creek Hatchery was rebuilt in 1982 and started to use naturally returning stocks from Scott Creek and the San Lorenzo River.

The MBSTP and CDFG has reared and released over 1,150,000 juvenile coho salmon and steelhead in local watersheds from 1976 through 1992 (Streig 1993). From March through May of 1992, the MBSTP and CDFG released 1,870 juvenile coho and 123,000 juvenile steelhead throughout various local streams (Streig 1993). Locations of the salmon and steelhead plants include: the San Lorenzo River and tributaries Bear Creek, Boulder Creek, Branciforte Creek, Fall Creek, Newell Creek, and Zayante Creek; Aptos Creek; Arana Creek; Carmel River and tributaries; Corralitos Creek; Pajaro River and tributaries Little Arthur and Uvas Creeks; Salinas River and tributary Arroyo Seco; San Vicente Creek; Scott Creek and tributary Big Creek; Soquel Creek; Tar Creek; and Waddell Creek (Table 4).

As of June 1992, MBSTP was rearing a total of 214,085 fry which included: 16,540 coho salmon, 26,980 Carmel River steelhead, and 134,240 steelhead from an assortment of local creeks in California. Also, 32,365 chinook salmon from the Feather River, California, were reared at Moss Landing in Monterey Bay (Streig 1993).

When adult coho salmon return to Scott Creek and the San Lorenzo River, the MBSTP traps the entire run, spawns them artificially, and then releases the smolts to help augment natural production. All released smolts are fin clipped and are not used as brood stock in subsequent years.

HISTORICAL AND CURRENT ABUNDANCE

Regional Overview

From the available literature it appears that coho salmon historically used most of the accessible coastal streams in California south to Monterey Bay (Berger et al. 1982, Brown and Moyle 1991, Hassler et al. 1991). Based upon monitoring of the runs by CDFG in the Klamath River (Iron Gate Hatchery), Trinity River (Trinity River Hatchery), Mad River (Mad River Hatchery), Noyo River (Noyo River Station), Russian River (Warm Springs Hatchery), plus scattered and irregular observations elsewhere, it appears that coho salmon populations in coastal streams throughout California are about one-third of their 1965 abundance levels (CDFG 1991, Brown and Moyle 1991). In the mid-1960's the average annual coho spawning run for all California streams was estimated at 99,000 fish (California Advisory Committee on Salmon and Steelhead Trout 1988, CDFG 1991). The wild populations of coho salmon may be as low as they have ever been; in the 1980's, the average annual run of natural spawners was estimated to be 30,500 (CDFG 1991), which represents approximately 1 percent of the 1940's levels (Brown and Moyle 1991). However, fish from hatchery populations make up about 57 percent of this total and many other populations probably contain at least some fish of recent hatchery ancestry (Brown and Moyle 1991). Brown and Moyle (1991) estimated that there are probably less than 5000 wild coho salmon spawning in California each year, and many of these fish are in populations that contain less than 100 individuals. Brown and Moyle (1991) also estimated that annual wild coho salmon populations in river basins retaining indigenous populations to be between 100 and 1,320 fish, with a more realistic estimate of 600 fish statewide.

There are few good historical accounts of the abundance of coho salmon in California, and those early records usually dealt with commercial salmon fisheries in general (Jensen and Startzell 1967). Consequently, those early records did not contain quantitative data by species until the early 1950's. Today, coho salmon stocks are intensively managed along the west coast. Coastal waters from the Mexico border to Cape Flattery, Washington, are partitioned into numerous management zones with escapement goals set for each zone. Monterey Bay falls within the management zone that stretches from Horse Mountain, just north of Fort Bragg, California, to the Mexico Boarder. The principal concern in each management zone is to allow for adequate reseeding of coho salmon habitat by setting escapement goals for Oregon Coastal Natural (OCN) coho salmon. The term OCN coho designates a stock aggregate comprised of the naturally produced coho salmon from Oregon coastal streams. This stock aggregate constitutes the largest proportion of naturally produced coho salmon caught in ocean salmon fisheries off

California and Oregon (PFMC 1993). Therefore, OCN coho salmon contribute extensively to the ocean commercial harvest, but also tend to set the allowable coho salmon harvest rate for combined natural and hatchery production for any given year. In 1991 and 1992, total commercial landings of coho salmon in San Francisco and Monterey Bay were 53,300 fish and 23,300 fish, respectively (Table 5). Total recreational landings of coho salmon in San Francisco Bay and Monterey Bay were 9,300 fish and 3,100 fish, respectively.

Recent commercial and sport ocean salmon landing records provide information on the size and species composition of the catch. However, data on individual river systems and state contributions are limited. The California Department of Fish and Game (1991) estimated the percent of historical salmon production by watershed in California, and the watersheds south of San Francisco Bay were cited as contributing approximately 2 percent of the total state production of coho salmon. The following review will concentrate on watersheds known to have contained coho salmon including the Sacramento River and tributaries, San Francisco Bay tributaries, and all watersheds continuing south to Monterey Bay.

Sacramento River and Tributaries

It is uncertain whether coho salmon were ever indigenous to the Sacramento River system. Several authors have reported coho salmon occurring within the Sacramento River system before the turn of the century (Jordan and Jouy 1881, Jordan and Gilbert 1881, Lockington 1881 as reviewed by Brown and Moyle 1991). Eigenmann (1890) reported coho salmon as one of four species occurring within the Sacramento River, but it was not a species of great concern compared to the large size and numbers of chinook salmon available.

Hallock and Fry (1967) reported that two coho salmon were identified at the Coleman National Fish Hatchery, one in the fall of 1949 and one in the fall of 1950. To try and establish a self-sustaining run of coho salmon in the Sacramento River system, CDFG stocked 43,025 coho salmon fry into Mill Creek in 1956, 53,500 in 1957, and an additional 48,000 in 1958 with coho salmon stock from the Lewis River, Washington (Hallock and Fry 1967, Fry 1973). The returning adult coho salmon returned primarily to Battle Creek, California, where the fish had been raised, and Mill Creek, California, where they were planted. Some of the returning adults to the Coleman Fish Hatchery were spawned and the offspring were reared and released at the Nimbus Fish Hatchery (Hallock and Fry 1967). The Nimbus Hatchery had 99 adult coho return in 1960, and 87 adults return in 1961 (Hallock and Fry 1967). In 1970, 58 coho salmon entered the Feather River Hatchery, were spawned, then released as fry (Schlichting 1974, Painter et al. 1977).

Due to the effects of hydraulic mining, dams, and water diversions occurring at the time, and the life history pattern of coho salmon, it is likely that coho salmon would have been the first salmonid species to become extirpated in the Sacramento River systems (Brown and Moyle 1991). There are a few coho salmon that stray into the Sacramento River currently, but there is known established run.

San Francisco Bay

Before human disturbances, spawning migrations of coho salmon occurred in most of the San Francisco Bay tributaries that contained suitable habitat (Leidy 1983). Fry (1936) reported coho salmon were observed from Corte Madera Creek (San Anselmo), and spawning took place in Corte Madera and Mill Valley Creeks (Hallock and Fry 1967). Leidy (1984) captured several juvenile coho salmon from both Corte Madera and Mill Valley Creeks, and juvenile coho salmon also were recently observed in Corte Madera Creek (Cox pers. comm.). These fish may still be successfully reproducing in these tributaries, or are the progeny of strays from other systems. No records exist on the numbers of coho salmon that historically utilized San Francisco Bay streams, however, if coho salmon historically used the Sacramento River tributaries and most suitable coastal tributaries and bays, it would seem that coho salmon populations did at one time exist within the San Francisco Bay Streams (Brown and Moyle 1991).

California Streams South of San Francisco Bay

There are a total of 34 streams that drain directly into the Pacific Ocean in San Mateo County, 25 streams in Santa Cruz

County, and 27 streams in Monterey County. Of the 86 total streams with direct coastal access, 13 were known to historically support coho salmon until the early 1970's including: San Gregorio Creek, Pescadero Creek, Butano Creek, and Gazos Creek within San Mateo County; Waddell Creek, Scott Creek, San Vicente Creek, San Lorenzo River, Soquel Creek, Aptos Creek, and Pajaro River within Santa Cruz County; and Carmel River and Big Sur River within Monterey County (D. Streig pers. comm., J. Smith pers. comm., J. Nelson pers. comm., Hassler et al. 1991, Brown and Moyle 1991). Berger et al. (1982) reported that at the turn of the century, coho salmon may have utilized all coastal accessible rivers as far south as the Santa Maria and Santa Ynez Rivers in San Luis Obispo and Santa Barbara Counties, respectively.

Most of the natural production of coho salmon in streams south of San Francisco Bay has now been lost (Brown and Moyle 1991, Hassler et al. 1991, Marston 1992, Nelson 1993). An accumulation of human related factors such as urbanization, agriculture, water diversions, logging, and hatchery practices in California coastal watersheds have apparently significantly reduced wild coho populations at the southern end of their range (San Lorenzo River Watershed Management Plan 1979, Berger et al. 1982, Baker and Reynolds 1986, California Advisory Committee on Salmon and Steelhead Trout 1988, Snider 1989, Smith 1992, CDFG 1992). In addition to the human related effects, the droughts of 1975-1977 and 1987-1992, the floods of 1982, 1983, and 1986, the strong El Niño that has persisted along the Pacific west coast, coupled with the highly erodible soils and unstable slopes typically found within California, exacerbated all negative impacts caused by humans (Smith 1992, CDMG 1992).

Of the 13 streams and rivers known to historically support coho salmon south of San Francisco Bay until the mid-1970's, only Scott Creek, Waddell Creek, and the San Lorenzo River in Santa Cruz County have coho salmon returning (Brown and Moyle 1991, Marston 1992, Smith 1992, Nelson 1993), which indicates a 77 percent reduction in the number of watersheds utilized by coho salmon south of San Francisco Bay.

Access to Waddell Creek, Scott Creek, and the San Lorenzo River during most of the normal coho salmon spawning period, and through a portion of the juvenile outmigration period, is very limited due to the intensity of the rainfall and subsequent heavy storm flows (Shapovalov and Taft 1954, Smith 1992, Nelson 1993). Quantitative information based on the numbers of returning adult and outmigrant juvenile coho salmon acquired from trapping is limited. However, combined with juvenile electrofishing results, these data could indicate general population trends.

Scott and Waddell Creek still maintain natural runs of coho salmon, and the MBSTP maintains a hatchery population in the San Lorenzo River. The coho populations of these three systems are discussed below.

Waddell Creek

Shapovalov and Taft (1954) intensively studied the life history of coho salmon and steelhead trout within Waddell Creek, with some references to Scott Creek. During the nine seasons of operating an upstream trap, 1933-1934 through 1941-1942, 2,218 adult coho salmon were trapped, with seasonal runs varying from 84 (1937-1938) to 583 (1934-1935). Accounting for the number of coho salmon observed jumping over the trap and spawners below the trap, Shapovalov and Taft estimated the total adult coho salmon spawner population of Waddell Creek to range between 120 (1938-1939) to 633 (1934-1935), with an average annual run size of 313 adults. The numbers of returning adult coho salmon in Waddell Creek fluctuated with no specific trend (Figure 2). However, Waddell and Scott Creeks, received numerous coho fry stockings from outside sources totalling more than 116,000 in Waddell Creek from 1913 through 1933, and 387,413 in Scott Creek from 1915 through 1939 during the Shapovalov and Taft study (1954).

Today Waddell Creek maintains a natural run of coho salmon, but it is quite reduced (D. Streig pers. comm, Brown and Moyle 1991, Marston 1992, Smith 1992, Nelson 1993). An adult migrant trap was operated in Waddell Creek in the winter of 1991-92 and captured 31 adult coho which represented one-half of the adult run based upon recovery of marked carcasses (Smith 1992). Smith (1992) found that most coho were grilse males (aged 1.1), and approximately 8 females were estimated for the 1991-92 run.

In the spring of 1992 a smolt trap was operated in Waddell Creek during part of the outmigration period and no coho smolts were captured (Smith 1992). Smith (1992) also electrofished 871 m of Waddell Creek, representing 3-5 individual habitats, in 13 locations over the estimated 9.6 km of potential coho habitat. He found a total of 19 juvenile coho in 6 of 13 sites sampled compared to 1505 juvenile steelhead sampled in the same locations, primarily in deeper glides and pools with some form of macrocover. He reported that available coho habitat in Waddell Creek was under-utilized. By late summer in 1992, steelhead outnumbered coho 14 to 1 in Waddell Creek (Smith 1992). Precise estimates of the number of juvenile coho in Waddell Creek could not be made. However, Smith (1992) estimated that the 1992 production of juvenile coho probably did not exceed the low to mid hundreds, which would represent 10-25 returning adults using a high survival estimate of 5 percent.

In 1992-93, one coho adult was trapped in Waddell Creek, however, Smith (1993) reported that trapping efficiency was very poor or non-existent due to high storm flows during two-thirds of the adult coho spawning run from mid-December through mid-February.

Smolt trapping in 1993 collected 119 coho, with the peak of downstream migrants occurring in mid-May (Smith 1993). Only 4 coho smolts were collected after 22 May and the last fish was collected on 10 June 1993 (Smith 1993). Smith (1993) could not estimate the total smolt production in 1993, because no trapping occurred prior to 4 April, and trap efficiency was poor due to high flows and clogging prior to 24 April.

Shapovalov and Taft (1954) operated an outmigrant trap for nine seasons (1933-1942) in Waddell Creek and trapped a total of 18,362 juvenile coho salmon. The number of juvenile coho salmon trapped ranged from 152 juveniles (1940-41) to 4,911 juveniles (1935-36), with a mean annual catch of 2,040 juvenile coho salmon. Assuming that trapping efficiency during the Shapovalov and Taft study was similar to present-day trapping efficiency, indicates that there is an approximate reduction of 75 percent in the numbers of coho salmon smolts produced in Waddell Creek since the 1930's.

The present adult spawning run in Waddell Creek is about 50 fish in a decent year and much less in poor years (D. Streig pers. comm., Smith 1993). Surveys of juvenile coho salmon indicate that Waddell Creek only has a good run every third year; the most recent in 1990, with poor 1988 and 1989 year class production (Brown and Moyle 1991, Smith 1993). The average annual coho returns estimated by Shapovalov and Taft (1954) during the 1930's and early 1940's compared to the 1992-1993 estimated adult coho run size (Smith 1993) indicates there is an 84 percent reduction in the numbers of returning adult coho salmon to Waddell Creek over the last 50-60 years.

Scott Creek

Smith (1990) observed an over-all reduction in lagoon depth and size in Scott, Pescadero, San Gregorio, and Waddell Creeks due to increased sediment deposition, primarily from the lack of sustained flushing flows beyond winter storm flows. Smith (1990) concluded that the fishery resources within the lagoons were significantly affected by artificial sandbar breaching and reduced flows from water diversions and drought conditions during the late 1980's.

A downmigrant trap for juvenile salmonids in Scott Creek, operated by CDFG for 9 weeks in the spring of 1992, captured 632 steelhead (identified as 55 wild smolts, 314 hatchery smolts, and 263 parr) and only 10 coho salmon (Nelson 1993).

In June and July of 1992, CDFG electrofished the lower 0.8 km of Scott Creek, representing 3 habitat types (riffles, flatwaters, and pools), to try and assess the fishery population and available habitat present under decades of chronic stream dewatering by adjacent landowners (Marston 1992). CDFG captured 3 coho in the lower Scott Creek and none within the lagoon, with numerous steelhead and sculpins in the samples. Marston (1992) estimated the total number of juvenile coho for 1087 m of stream in lower Scott Creek to equal 18 fish (8 in flatwater and 10 in pools), and the total number of juvenile steelhead was estimated at 7755 fish (1839 in riffles, 2080 in flatwater, and 3836 in pools) in the same reach. Marston (1992) concluded that water diversions were significantly affecting lower Scott Creek and the lagoon aquatic habitats for salmonid species, and that lagoon constrictions, disease (i.e. Bacterial Kidney Disease), and possibly interspecific competition with juvenile steelhead for food and space were limiting coho salmon production. Currently, CDFG is conducting an Instream Flow Incremental Methodology (IFIM) study within this reach to determine optimum flows and has established an interim bypass flow of 0.06 m^3/sec until the study is completed in 1994 (Nelson 1993).

Smith (1992) electrofished 495 m of Scott Creek, representing 3-5 individual habitats, in 13 locations over the estimated 17.5 km of potential coho habitat. He found a total of 42 juvenile coho in 6 of 13 sites sampled compared to 1266 juvenile steelhead sampled in the same locations, primarily in deeper glides and pools with some form of macrocover. Smith (1992) estimated that the total juvenile coho salmon production for 1992 in Scott Creek to be less than one thousand fish, which would represent 25-50 returning adults using high a survival estimate of 5 percent.

An adult migrant trap in Scott Creek, operated from 29 January to 8 February 1993 by CDFG, captured 10 adult coho salmon consisting of 5 males and 5 females ranging from 45-78.5 cm FL. However, due to poor trapping efficiency no quantitative estimate was made for the 1992-93 spawning season (Nelson 1993).

CDFG operated a downmigrant trap for juvenile salmonids in Scott Creek for 11 weeks in the spring of 1993. They captured 1065 steelhead (identified as 161 wild smolts, 284 hatchery smolt/pre-smolt, and 620 parr) and 114 coho salmon (identified as 60 wild smolts, 46 hatchery smolts, and 8 young-of-year), with peak migration occurring the week of 17 May 1993 on a receding hydrograph of 0.05 m^3/sec (Nelson 1993).

Scott Creek and its tributaries, namely Big Creek and Mill Creek, have been the sites of exhaustive rehabilitation efforts by the MBSTP and CDFG respectively. This watershed and the Waddell Creek watershed are considered the best habitats available for anadromous species south of San Francisco (D. Hope pers. comm., D. Streig pers. comm., J. Smith pers. comm., J. Nelson pers. comm, K. Anderson pers. comm., Snider 1989, Marston 1992).

Today, the coho salmon run size in Scott Creek averages between 30-40 fish per year (Table 6). Unlike Waddell Creek, no older records with estimated numbers of returning adult coho salmon were found for Scott Creek. Because Scott and Waddell Creeks have similar watersheds and are located adjacent to one another, an estimated run size could be calculated for Scott Creek during the 1930's and 1940's. Using the average annual coho returns estimated by Shapovalov and Taft (1954) during the 1930's and early 1940's in Waddell Creek (313 adults), adjusted for the additional estimated 7.9 km of accessible coho habitat in Scott Creek (Smith 1992), indicates there has been a 93 % reduction in the number of returning adult coho salmon to Scott Creek over the last 50-60 years.

San Lorenzo River

The San Lorenzo River is now considered the southern-most drainage to receive returning adult coho salmon, although it is primarily maintained by hatchery releases of coho salmon stock from Scott Creek and other watersheds (Streig 1993). The San Lorenzo River is believed to have lost its naturally spawning coho salmon population during the 1976-77 drought (Streig 1993).

Johnson (1964) estimated the annual angler catch of coho salmon in the San Lorenzo River to be between 200-1,500 fish, with an estimated average annual run of 1,000 adults. The estimated total angler catch of coho salmon in the San Lorenzo River during the winters of 1970-71, 1971-72, and 1972-73, were 383, 370, and 342 coho salmon, respectively (Johansen 1975). Coho salmon lengths ranged from 32.0-89.0 cm FL, with a mean of 66.7 cm FL in 1971-72, and from 33.4-80.0 cm FL, with a mean of 51.3 cm FL in 1972-73 (Johansen 1975). Comparing previous years of angling catch rates, Johansen (1975) reported a decline in the annual angling catch of coho salmon and steelhead in the San Lorenzo River from recorded catchs from the previous 20 years. Data from the fish trap operated at the Felton water facility in the City of Santa Cruz support these observations. During the first winter of operation in 1976-77, the station recorded an upstream movement of only 174 coho salmon and 1614 steelhead (San Lorenzo River Watershed Management Plan 1979). The 1977-78 coho salmon run past Felton fish trap was 182 adults, and steelhead numbered less than 600 adults (San Lorenzo River Watershed

Management Plan 1979). In 1980-81, 16 adult coho salmon were checked through the Felton fish trap (Scott 1981).

Although fish populations may normally experience annual variations, these figures indicate a major decline in fish numbers. The decline in salmonid numbers are attributed to urban development, water diversions, and poor logging practices within the watershed which have decreased habitat and increased siltation and stream temperatures (Johansen 1975, San Lorenzo River Watershed Management Plan 1979). Field studies indicate that fine sediments within the San Lorenzo River increased from 8 percent in 1966 to 65 percent in 1972 (Lang 1966, 1972). Urban development and logging has removed the riparian vegetation and decreased the capability of soils to retain runoff.

The MBSTP and CDFG still operate an adult migrant trap at the Felton Water Facility, but quantitative trapping data is limited (Table 7). The present coho salmon run in the San Lorenzo River is estimated to be between 75-125 fish per year (D. Streig pers. comm.). Using the mean estimated annual run size reported for the San Lorenzo River in the 1960's (650 adults), indicates there has been an 85 percent reduction in the number of returning adult coho salmon to the San Lorenzo River over the last 30 years.

GENETICS

In order to manage and preserve coho salmon populations, basic information on genetic variability and gene flow in subpopulations and stocks are essential. Several protein electrophoretic studies have demonstrated distinct population structure between some coho populations. However, early studies show that coho salmon display the lowest level of allozyme variation of all Pacific salmon species (Allendorf and Utter 1979, Reisenbichler and Phelps 1987, Johnson et al. 1991). This is due, at least in part, to the choice of loci available to those early researchers.

In earlier studies focusing on single loci, the transferrin locus was found to be polymorphic. Allendorf and Utter (1979) found a significantly lower frequency of the B allele of transferrin in Fraser River and Columbia River coho salmon compared to other sampled populations. Suzumoto et al. (1977) and Winter (1978) reported differential resistance to bacterial kidney disease (BKD) among transferrin genotypes. Pratschner (1978) reported differential mortality from vibriosis, furunculosis, and cold-water disease between transferrin genotypes. Thus, transferrin polymorphisms may be maintained by a selective mechanism and may reflect adaptive properties of the different genotypes rather than ancestral relationships (Johnson et al. 1991).

Most other loci examined in coho salmon populations have been less informative. May (1975) reported a variant allele of lactate dehydrogenase (LDH-4, now called LDH-B2*) which showed a clear separation between south Puget Sound/Hood Canal and north Puget Sound, as well as Strait of Juan de Fuca and Washington coast coho salmon stocks. Utter et al. (1980) reported data from several studies on unusual allelic variants in coho salmon from the Feather River Hatchery in California, and suggested that these variants may occur widely in the southern part of the coho salmon range. Wehrhahn and Powell (1987) found distinct allelic frequency differences between fish from the lower coastal mainland of British Columbia and Oregon.

Hjort and Schreck (1982) studied electrophoretic, morphological, and life history characteristics of coho salmon in Washington, Oregon, and California. In general, they found based on the three criteria, that stocks geographically close were similar, stocks in large rivers were more similar to each other than to stocks from smaller stream systems (independent of geographic proximity), hatchery stocks were more similar to each other than to wild stocks, and wild stocks were more similar to each other than to hatchery stocks. However, transferrin A allele frequencies were high in stocks from large stream systems regardless of lattitude, and in southern stocks regardless of stream size.

Solazzi (1986) used electrophoretic data to identify five groups of coho salmon in Oregon and California. In California, the Klamath River, Trinity River, Mill Creek, and Prairie Creek coho salmon were grouped with the Rogue River and Columbia River. Based on Solazzi's dendrogram on genetic similarities, California samples were genetically more diverse than samples from the Oregon coast or the Columbia River coho salmon populations.

Scott (1993) used electrophoretic analysis to study 9 genetic loci of coho salmon in Waddell Creek compared to coho salmon from the Noyo River (Mendocino County) and Trinity River (Trinity County). He found that Waddell Creek coho salmon showed a significant difference from Trinity River coho salmon at 2 of 3 loci (GL-2 and LDH-1, now called PEPC* and LDH-A1*, respectively), and a probable difference from the Noyo River coho salmon at 2 of 3 loci (Tfn, GL-2). However, Scott concluded that his sample sizes were too small to draw over-all statistical significance.

Observations of wild coho salmon stocks in ten northern California streams (Navarro River and tributary Flynn Creek, Little River, Russian Gulch, Casper Creek, Hare Creek, Noyo River and tributary Kass Creek, Pudding Creek, and Ten Mile River) demonstrated four distinct foraging phenotypes that combine unique microhabitat distributions, foraging behavior, growth and developmental patterns (Nielsen 1994 in press). In general, Nielsen found that trends in genetic polymorphism were variable among the foraging phenotypes and between hatchery and wild populations, suggesting that adaptive responses to environmental influences and not genetic variation lead to coho polyphenism.

Allozyme analysis of hatchery coho from the Mad River Hatchery (Humboldt County) and the Warm Springs Hatchery (Sonoma County) indicated that these populations carried 14 rare alleles not found in samples taken from the wild coho population in the Noyo River, Mendocino County (Nielsen 1994 in press). Of the rare alleles shared between the hatchery and wild populations, 44 % were found in the Noyo River wild stocks. Variant alleles found in the Warm Springs fish but not in the Mad River hatchery population included the following loci and relative mobility: CK-A2*110 and FBALD-4*105. Alleles found in the Mad River hatchery population but not in Warm Springs hatchery population included: sAAT-1,2*110, sIDHP-3*130, sMDH-A1,2*120, and PGM-1*150. Nielsen concluded that the resulting population of wild and hatchery fish suffered from disruption of the existing social system due to antagonistic interactions, reduced diversity of foraging behavior, changes in genetic polymorphism, reduced production of wild forms, and a possible reduction in wild reproductive potential. Fraser (1969) reported that when juvenile densities are high, growth of coho salmon is depressed through intraspecific competition for resources and mortality is increased. Shapovalov and Taft (1954) noted an inverse correlation between the number of downstream migrants and adult return, implying that in years when intraspecific competition is low, greater numbers of downstream migrants return to spawn as adults in Waddell Creek.

Mitochondrial DNA testing on wild and hatchery coho salmon from the Noyo River in California revealed five mtDNA types varying at 10 sites (Nielsen et al. 1994 in press). More mtDNA haplotypes were found, on average, in contemporary hatchery populations than in geographically proximate wild stocks. Nielsen et al. (1994 in press) reported that the factors potentially leading to genetic differences in hatchery and wild coho salmon stocks sampled were historic introductions of geographically divergent populations into the hatchery brood stocks, and lack of introgression of geographically divergent genotypes from the hatchery into wild coho populations.

Bartley (1987) used allozymes to examine the genetic structure of 27 populations of coho salmon from northern and central California (Table 8). Wild and hatchery coho salmon samples were collected from 1983 through 1986 (Table 9). The allozyme data were compiled for the 27 populations sampled consisting of 23 polymorphic loci (Table 10). The 100 allele at each locus was common in nearly all groups with the exception of the PEPD-2(80) allele being the most prevalent in Flynn Creek and Kass Creek. Bartley observed allozyme variation at 24 of 45 (53 %) gene loci, but much of the observed variation was due to rare and uncommon alleles in only a few groups (frequency < 5 %). Of the 30 variant alleles identified, 20 (67 %) occurred in three or fewer groups.

Average genetic identity between California coho salmon sampled by Bartley was 0.996. Intra-group variation accounted for 84 % of the total genetic variation with only 16 % due to the differences between the groups. Only weak associations between genetic identity and geographic location were found (Figure 3). Little pattern in the distribution of variant alleles or genetic variation was observed. The CK-2(85) allele was present at frequencies of 0.35 and 0.138 in the groups from Huckleberry Creek and Redwood Creek, respectively, both tributaries to the South Fork Eel River. The allele was found to be absent from Butler Creek which is also a tributary to the South Fork Eel River. The GPI-3(85) allele was found to be exclusively in the three groups of coho salmon from the Trinity River watershed including Rush Creek, Deadwood Creek, and the Trinity Hatchery. The IDDH-1(150) allele was present in the three South Fork Eel River groups (Butler Creek, Redwood Creek, and Huckleberry Creek), but was also found in Kass Creek and Pudding Creek. The LDH-4(115) allele was predominately found in the groups south of the Russian River. However, this allele was absent from Scott Creek and Waddell Creek, but was present in Casper Creek and Elk River.

The low level of allozyme variability in groups of coho salmon from California reported by Bartley (1987) was characteristic of coho salmon populations in the Pacific Northwest (Utter et al. 1970, Utter et al. 1973, Olin 1984). Olin (1984) found 31 of 53 (58 %) loci to be polymorphic in 23 groups of coho salmon from Oregon; the variability in the Oregon groups was also due to numerous rare alleles with limited distribution.

Average heterozygosity estimates reported by Bartley (1987) ranged from 0.000 (Scott Creek) to 0.050 (Waddell Creek), with a mean of 0.027 (Table 11), and was in the range previously reported for coho salmon. Allendorf and Utter (1979) reported a value of 0.015 for coho salmon from Oregon and Washington. Nielsen et al. (1994 in press) reported heterozygosity values for wild coho salmon populations sampled from 10 basins along the Mendocino coast line ranging from 0.018 (Little River) to 0.043 (Noyo River), with a mean of 0.029. Olin (1984) found heterozygosity values ranging from 0.026 to 0.052, with a mean of 0.04, for coho salmon from Oregon. The average heterozygosity reported by Bartley (1987) was lower than Olin's estimate since 10 of 27 groups from California had estimates lower than the minimum value found for coho salmon groups from Oregon. The lower heterozygosity may be a natural feature of populations from the southern limit of the species' range (Mayr 1963). Harsh environmental conditions at the limits of the species range may increase selective pressures thereby eliminating some less fit genotypes. Similarly, smaller population sizes may exist in such marginal habitats and may have resulted in low genetic variation through random genetic drift; on the other hand, the heterozygosity estimates reported by Bartley (1987) did not display any north-south cline.

Bartley (1992) reported that the genetic variability among coho salmon populations was low throughout California, estimating the average number of individuals exchanging genes (Nm) among the California populations of coho salmon studied was 1.3 fish per generation. Nielsen (1994 in press) also found that genetic exchange among coho salmon sampled from 10 streams in Mendocino County, ranged from 0.5 to 2.9, with a mean of Nm >1.6 per generation. The distribution of gene flow was similar to the distributions reported by Slatkin (1981) who indicated that genetic exchange among stocks with Nm >1, would be sufficient to prevent genetic differentiation through the effects of genetic drift alone (Slatkin 1985). Bartley (1992) concluded that coho salmon may not be genetically differentiated on a geographic basis within their range in California, but may show differentiation when examined on a coastwide basis. Therefore, attempting to characterize different subpopulations or even coho salmon from a broad section of California with isozyme technology would be difficult.

Bartley (1987) found no patterns of allele frequency throughout coho salmon groups studied in California, but Utter et al. (1970, 1973) and Allendorf and Utter (1979) found significant differences in the frequency of transferrin alleles between groups of coho salmon from Puget Sound and the Columbia River system. Coho salmon populations in California are largely restricted to coastal rivers and do not utilize any river system with as many tributaries, or requiring as extensive an inland migration as the Columbia River system. Therefore, the potential for isolation and genetic differentiation between inland and coastal populations found in more northern watersheds does not seem to exist for coho salmon populations in California.

The literature on genetic studies and planting records of coho salmon shows that the majority of coho salmon streams in California have been planted with coho salmon stocks from outside their native watersheds, and very few genetic studies have been conducted on native California coho salmon stocks. The genetic effects of stocking non-native coho salmon on native coho salmon populations have been largely unknown, but are now being investigated (Steward and Bjornn 1990, Nielsen 1994 in press). Genetic changes in hatchery stocks of Pacific salmon have been documented and models have recently been constructed to aid in understanding the consequences of these changes for the preservation of wild genotypes (Waples 1990a, Waples 1990b, Waples and Teel 1990).

EFFECTS OF DISEASE

The petitioner stated that the effects of disease have led to the decline of central California coho salmon populations. As a rule disease is not prevalent among salmon populations in their natural environment. Occasionally epidemics occur, often due to unusual environmental conditions, such as abnormally high water temperatures, which could allow one or more disease organisms (ie. protozoa or bacteria) to flourish and cause considerable mortalities on salmonids due to physiological stress. In hatcheries and rearing ponds, in which large numbers of fish are concentrated to a far greater extent than in their natural environment, diseases are much more common.

Shapovalov and Taft (1954) reported that during their investigations of coho salmon in Waddell Creek, there were no known losses of coho salmon due to high water temperatures or lack of oxygen, and very little evidence of disease causing mortality was observed. Furunculosis was cited as causing some mortalities in unspawned adult steelhead, but was not observed in the adult or juvenile coho salmon population. All adult coho salmon were believed to have succeeded in spawning before dying, and no large mortalities of young salmon were observed in the wild or in holding tanks.

Fungus (Saprolegnia parasitica) was also cited as being present in Waddell Creek by Shapovalov and Taft (1954), however, it is present in most salmonid streams. It is a secondary infection on breaks of the skin caused by mechanical injury or disease, and on eggs under abnormal environmental or hatchery conditions.

In reviewing pathology reports for the Big Creek Hatchery (1990-1993), the following list of diseases were compiled by CDFG (Cox 1993);

Ectoparasites:

Gyrodactylus sp., *Epistylis* sp., *Costia necatrix*, *Ichthyopthirius multifilis*, *Chilodinella* sp.,

Gill parasites

Loma sp., Amoeba,

Bacteria:

Bacterial Kidney Disease (*Renibacterium salmoniarum*), Myxobacteria (*Flexibacter columnaris*, *F. psychrophila*);

Environmental:

Bacterial gill disease (multiple species), gas bubble disease.

Bacterial Kidney Disease (BKD), which is caused by the slow growing *Renibacterium salmoninarum* is highly infectious and can be transmitted directly by feeding of raw viscera from infected fish, or horizontally from infected fish sharing the same water supply, and has conclusively been shown to be transmitted vertically (Elliott et al. 1989).

Recently BKD has been detected at the Big Creek Hatchery (MBSTP) in both steelhead and coho salmon populations (Cox 1992). Of the returning coho salmon trapped in Scott Creek and the San Lorenzo River in 1991-1992, clinical BKD (gross pathological symptoms present) was observed in 84.6 percent (11/13) of those from Scott Creek and 27.3 percent (6/22) of those from the San Lorenzo River at the time of spawning (Cox 1992). The overall incidence of BKD measured by DFAT (direct fluorescent antibody technique) among Scott Creek coho salmon was 100 percent (13/13) and among San Lorenzo River fish was 95.5 percent (21/22). Waddell Creek coho salmon are also suspected of having near 100 percent infection of BKD (Streig pers. comm.).

Sampling of coho salmon populations from north coast watersheds, including the Warm Springs Hatchery in the Russian River watershed, have shown that BKD is present in most drainages (Cox pers. comm.). Despite many years of research on BKD, the pathogenesis and epizootiology remain poorly understood, and is considered to be the most difficult of bacterial fish diseases to control (Elliott et al. 1989).

Starting in 1992, CDFG initiated a treatment protocol to try and control BKD outbreaks within the Big Creek and Warm Springs Hatcheries (Cox 1992). Treatments include erythromycin injections to female coho salmon prior to spawning, and prophylactic feeding of erythromycin to juvenile coho salmon. Prior to erythromycin injections, Cox (pers. comm.) found that fish located above the Big Creek Hatchery were less infected than fish below, and in 1993 data has shown that the incidence rate has been reversed within the watershed. The problem with using erythromycin injections is that they have to be given to the female 2 to 3 weeks prior to spawning. Many of the adult coho salmon entering Scott Creek, and most small coastal watersheds, usually spawn within a few days of entering the streams and therefore are not held long enough to apply effective treatments.

Prior to treatment of coho salmon in the Big Creek Hatchery, egg viability was found to be very low (< 70 percent) due to the transmission of BKD from the female's coelomic fluid into the eggs micropyle (Streig pers. comm.). Evelyn et al. (1986) found similar results in coho salmon from British Columbia, and that the male salmon played a relatively unimportant role in the vertical transmission of BKD to the offspring. Since the erythromycin injections started, greater egg viability and successful spawning has resulted in coho salmon within the Big Creek Hatchery (Streig pers. comm.). However, many of the coho salmon juveniles still harbor BKD, and there is probably a high mortality rate of smolting coho salmon when they enter the ocean. Once the juveniles migrate to sea, the rate of mortality on these infected fish is largely unknown, but is considered to be relatively high (Cox pers. comm.).

DISCUSSION

In this section, we address the two key questions raised at the start of this status review: Do Scott Creek and Waddell Creek represent a species as defined by the ESA? and, if so, is the species threatened or endangered? We begin by summarizing evidence developed in the status review that is relevant to the two criteria that must be met for a population to be considered an ESU, and hence a species under the ESA.

Reproductive Isolation

Straying Rates

Straying in coho salmon is well documented when access to natal streams is obstructed (Martin 1984). Quinn and Tallman (1987) evaluated the reported homing and straying of coho salmon from California to British Columbia, and found that homing under normal conditions was fairly accurate, ranging between 73 to 100%. Shapovalov and Taft (1954) studied the extent of homing and straying of coho salmon between Scott and Waddell Creeks, which are 7 Km apart. They reported that 85% of the fish marked at Waddell Creek returned there and 15% strayed to Scott Creek. Of the coho marked at Scott Creek, 73% returned there and 27% strayed to Waddell Creek. However, several marked coho salmon from Waddell Creek were captured in the Noyo River, California, 322 km to the north in 1937, and near the San Lorenzo River, in Santa Cruz County, 24 km to the south during their studies. These additional strays were not accounted for in their analysis, and they did not evaluate the straying of coho salmon into other local watersheds. The percentage of straying by coho salmon reported by Shapovalov and Taft (1954) should be considered a minimum straying rate and not an actual straying rate. As recently as 1992, marked coho salmon from Scott Creek have also been trapped in the San Lorenzo River. Therefore, reproductive isolation from other coastal coho salmon populations, even as far as north of the San Francisco Bay salmon streams, is not absolute. However, the straying rate with other coho salmon from watersheds south of San Francisco Bay is quite diminished due to the loss of most of the coho salmon populations within these watersheds.

Barriers to Migration

The petitioner felt that "because all streams south of San Francisco Bay had lost their coho salmon populations and all other coho salmon populations were separated by more than 50 miles, that coho salmon from Scott and Waddell Creeks should be considered a reproductively isolated stock of Pacific salmon." However, coho salmon from Scott and Waddell Creeks have been observed as far north as Fort Bragg (322 Km), and south (24 Km) to the San Lorenzo River (which has been extensively stocked with coho salmon from numerous other northern watersheds, and still annually stocked with Noyo River and Scott Creek coho salmon). Therefore, distance in the ocean is not a good measure of reproductive isolation from other coho salmon populations, though the chance of straying to other northern coho salmon populations, to a large extent, is greatly reduced.

Many small coastal streams in California and Oregon are closed by sand bars at their mouths during a portion of the year. Generally, fish cannot enter the stream until the sand bar is broken, usually by the first heavy rains. Although the formation of a sand bar may temporarily act as a migration barrier, it does not represent a reproductive isolation mechanism.

Genetic Data

The petitioners reported that Bartley found 0.00 heterozygosity for coho salmon in Scott Creek. The protein electrophoretic study conducted by Bartley (1987) showed that the largest level of differentiation, though quite low, was between Scott Creek (0.000) and Waddell Creek (0.050), the two California populations that were in the closest proximity.

The results from the limited number of allozyme studies conducted on coho salmon populations in California were similar to results obtained in Oregon, Washington, and British Columbia. However, little pattern in the distribution of variant alleles or genetic variation was observed, and only weak associations between genetic identity and geographic location were found.

Genetic variability found was low throughout California, and was usually due to a few rare and uncommon alleles. The average estimated number of individuals exchanging genes among the California populations of coho salmon studied was > 1.0 fish per generation, which is large enough to prevent the tendency for fixation of different alleles in different populations. Overall, the genetic data compiled for this status review failed to demonstrate that the Scott and Waddell Creeks coho salmon populations as a group are distinct from other coastal coho salmon populations.

Life History Traits

The petitioners stated that coho salmon spawning primarily occurs in January and February in Scott and Waddell Creeks, and the late spawning time should indicate reproductive isolation. In Waddell Creek, Shapovalov and Taft (1954) reported that 96 percent of all adult coho salmon were trapped during nine weeks from December 10 through February 10, mostly during the heaviest precipitation period. Shapovalov and Taft (1954) also reported that 83 percent of returning adult coho salmon passed upstream of the Benbow Dam on the south fork of the Eel River from November 26 through January 6 (1938-1944), and 81 percent of the returning adult coho salmon passed the Sweasey Dam on the Mad River from November 12 through December 23 (1941-1953). Shapovalov and Taft (1954) reported that coho salmon migrations started in November and continued through the beginning of March in the Eel River and the end of February in the Mad River, with peak spawning taking place in December and January in both systems. Adult coho salmon were trapped in Freshwater Creek (tributary to Humboldt Bay) in conjunction with peak storm flows, usually in December and January (Hull et al. 1989). Allen (1958) reported that adult coho salmon were trapped in Pudding Creek (Mendocino County) starting in mid-November through mid-February with increased stream flow. Bratovich and Kelley (1988) reported that coho salmon migrations begin in November and continued through January, with peak spawning taking place in December through January in Lagunitas Creek (Marin County) during peak storm flows. Researchers generally attribute the differences in spawning migrations to the increase of stormflow runoff (usually occurring earlier in the northern range of coho salmon populations), which allows the salmon to access lagoons/estuaries and higher up the river systems to their natal tributaries.

There has been an apparent shift in peak spawning migration timing within Scott and Waddell Creeks to later in the season since the studies of Shapovalov and Taft in the 1930's and 1940's. Spawning migrations in most California coastal streams and rivers have shifted to later in the spawning season, possibly due to degraded conditions within the watersheds, rivers, and estuaries. The loss of large organic debris within stream systems which helps flush out sediment and creates deep holding pools, excessive diversion of drought limited flows which increases water temperature and decreases available habitat, and the reduction in area and volume of most estuaries and rivers due to filling with sediment, may have created conditions in which coho salmon can no longer access or survive in rivers until the start of heavy winter rains.

Summary

Available information does not make a strong case for reproductive isolation of Scott Creek and Waddell Creek coho salmon. The loss of other coho salmon populations south of San Francisco Bay has decreased the chance of Scott and Waddell Creeks coho salmon mixing with populations from nearby watersheds, but the distances to other north-coast coho salmon streams are well within their migration range, as evidenced by their reported straying over the last 50 years. The results from the limited number of allozyme studies conducted on coho salmon populations in California were similar to results obtained in Oregon, Washington, and British Columbia. However, genetic data fail to show that Scott and Waddell Creeks coho salmon as a group are distinct from other coastal coho salmon populations. Although other explanations are possible, the year to year variation in the timing of coho salmon spawning migrations in Scott and Waddell Creeks are similar and within range of run times reported for other coho salmon populations in California and Oregon. The modest difference in peak spawn timing cited by the petitioner may reflect (or may be the result of) reproductive isolation, but the best available data is inconclusive regarding the cause of this difference. Although this does not prove that Scott Creek and Waddell Creek coho salmon are not reproductively isolated, it does mean that evidence to support reproductive isolation must be found elsewhere.

Evolutionary Significance

Habitat Characteristics

Adaptations to environmental conditions such as differences in the success of coho salmon redd survival in highly mobile sediment bedloads and extreme hydrological cycles, and survival of juveniles in warm summer water temperatures may contribute substantially to the ecological/genetic diversity of coho salmon species. However, many of the streams and rivers in California now exhibit similar elevated summer/fall water temperatures and extreme winter-flow bedload movements and hydrologic cycles. Human disturbance of these fragile aquatic ecosystems is evident on a large geographic scale. Management of most California watersheds over the last 100 years has created poor in-river conditions, which have negatively affected the life-history and success of self-perpetuating coho salmon populations. The active plate-tectonics, combined with the highly erodible soils and unstable slopes found within central California watersheds, is indicative of most California coastal watersheds. The success of early spawning coho salmon in Scott and Waddell Creeks is undoubtedly low compared to later spawning fish, but this pattern of differential survival may also occur in other California and Oregon streams and rivers.

Distinctive Life History Traits

Many of the life history traits cited by the petitioner as evidence for reproductive isolation are also important to consider with respect to the contribution of Scott Creek and Waddell Creek coho salmon to ecological/genetic diversity of the species. The petitioners state that "the production of 2,700 eggs per female shows the smaller average size of central California coho salmon, and therefore indicates evolutionary significance." Shapovalov and Taft (1954) found that egg production for Scott and Waddell Creek's coho salmon was between 2,782-2,789 eggs per female, and reported that egg production of Scott and Waddell Creek's coho salmon were within the range reported for other coho salmon populations throughout the west coast. Salo and Bayliff (1958) reported that the mean number of eggs produced by coho salmon in Minter Creek, Washington, was 2,500 per female. Fraser et al. (1983) reported that the mean number of eggs produced by coho salmon in the Big Qualicum River, British Columbia, was 2,574 per female. Shapovalov and Taft (1954, p.62) stated, "due caution must be observed in using data pertaining to egg content to indicate racial differences between populations in different rivers." They recognized that each river system is highly variable in year to year production, and that a smaller size of adult spawner may result from over-harvesting the larger individuals. We have no data to indicate that Scott and Waddell Creeks coho salmon egg production is related to the smaller average size of these fish in comparison to other coastal coho salmon populations.

Genetic Data

It is generally presumed that genetic characters detected by protein electrophoresis are largely neutral with respect to natural selection and therefore do not provide direct evidence about important adaptions. The occurrence of substantial genetic differences at neutral markers would suggest that there has been ample opportunity for selection to foster adaptive differences at other parts of the genome. Genetic data reviewed on coho salmon in Scott and Waddell Creeks, provides no evidence to suggest such adaptive differences.

Effects of Artificial Propagation

Although Scott and Waddell Creeks are generally considered to have the last remaining naturally reproducing coho salmon populations south of San Francisco, extensive hatchery plants of non-native stocks have taken place from the early 1900's through the 1970's from a variety watersheds throughout the west coast. The limited stocking records found during this status review indicate that over two million coho salmon have been stocked in Santa Cruz County streams. Scott Creek was stocked with approximately 400,000 coho salmon from 1915-1940, and over 10,000 coho salmon were planted during the late 1960's from the Darrah Springs Fish Hatchery and Noyo River. Waddell Creek was stocked with approximately 116,000 coho salmon from 1913-1933, and again with more than 10,000 coho salmon during the late 1960's from the Darrah Springs Fish Hatchery. An unknown number of coho salmon were planted in Waddell Creek in 1970 and 1972 from the Noyo and Trinity River Hatcheries. Scott Creek and Waddell Creek have not been stocked with non-native coho salmon stocks since the early 1970's. Many of the coho salmon releases in Santa Cruz County streams during the early 1900's involved early life history stages whose survival rate was likely very low. However, since the 1950's, juveniles planted in these streams and have probably contributed to the decline in returning numbers of coho salmon and to the current genetic makeup of coho salmon populations within these streams.

The large numbers of steelhead that have been planted in Scott and Waddell Creeks has also possibly contributed to the decline in returning coho salmon adults. Electrofishing and trapping results show a disproportionate number of steelhead to coho salmon juveniles. During the Shapovalov and Taft study of Waddell Creek, the reported ratio of steelhead to coho salmon was 2:1. More recent data indicates that the ratio of steelhead to coho salmon has increased four fold. This increase possibly has an effect in the reproductive success (redd super-imposition) and rearing capabilities (inter- and intra-specific competition) of coho salmon in Scott and Waddell Creeks. Degraded habitat conditions due to poor land-use management, in addition to increased steelhead production and plants exacebates the problem.

BKD was not found within the watersheds' salmonid populations until recently, suggesting that inter-basin stock transfers possibly introduced the disease problem. The high incidence rate of BKD among the populations within these watersheds suggests two things: 1) that populations of different genetic orgin have successfully interbreed with native Scott Creek and Waddell Creek coho salmon, and/or 2) hatchery practices within the watersheds have horizontally spread BKD to the native populations. The low level of genetic variability found throughout California, including Scott and Waddell Creeks, and the high rate gene exchange among the California populations of coho salmon studied (Nm > 1.0) suggests that some level of interbreeding has occurred between hatchery and native coho salmon populations.

Summary

It is generally accepted that naturally occurring species usually have some genetic variation that allows the species to persist in marginal habitats and environmental conditions that found at the periphery of its range. However, many of the distinctive habitat characteristics and life history traits exhibited by coho salmon in Scott and Waddell Creeks are not unique, but are shared with most coho salmon populations in California and Oregon. The extreme hydrologic cycles and resulting bedload movements undoubtedly has an effect on the success of early spawning coho salmon in Scott and Waddell Creeks, but these conditions are exhibited in most of California's coastal streams and rivers. Excessive use of drought limited flows in Scott and Waddell Creeks, as well as other systems, has probably exacerbated the problems of poor land use management and stream habitat conditions. The number of eggs produced by a female coho salmon, in and by itself, does not indicate differences between populations from other watersheds. The number of eggs produced by Scott Creek and Waddell Creek coho salmon were within the range reported from other coho salmon populations along the entire west coast. Even though Scott and Waddell Creeks have not been planted with outside sources of coho salmon since the early to mid-1970's, the effects of continuous hatchery plants may have affected any distinctive phenotypic and life history traits.

CONCLUSIONS

In reviewing the literature on the abundance of coho salmon in California, there is an indication that population levels are approximately one-third of their 1965 levels. Presently, the average annual total run of natural coho salmon spawners in all California streams is estimated to be 30,500, and fish from hatchery populations make up roughly fifty-seven percent of this total. Total estimated wild coho salmon number less than 5000 throughout California, and are primarily in individual populations containing less than 100 individuals.

Most of the natural production of coho salmon in streams south of San Francisco Bay have now been lost. Of the 13 streams known to have supported coho salmon populations until the 1970's, only three systems (23%) still have returning runs. Scott Creek and Waddell Creek still maintain natural runs of coho salmon, and a hatchery population exists in the San Lorenzo River. The numbers of returning adult coho salmon to Scott Creek, Waddell Creek, and the San Lorenzo River have declined over the last 50-

60 years, with estimated reductions of 93%, 84%, and 85%, respectively.

Available information does not make a strong case for reproductive isolation of Scott and Waddell Creeks coho salmon. Marked coho salmon from Scott and Waddell Creeks have been caught in the Noyo River 322 km to the north near Fort Bragg, California, and in the San Lorenzo River 24 km to the south in the City of Santa Cruz, California. Therefore, distance in the ocean is not a good measure of reproductive isolation from other coho salmon populations. The San Lorenzo River coho salmon population is primarily a hatchery maintained population and has been extensively stocked with coho salmon from numerous other northern watersheds for over 70 years. Although the loss of other coho salmon populations south of San Francisco Bay has isolated these coho salmon populations, the distance of the Scott and Waddell Creeks populations to other north-coast coho salmon streams is well within their migration range based on their reported straying over the last 50 years.

Many small coastal streams in California and Oregon are closed by sand bars at their mouths during a portion of the year. Generally, fish cannot enter the stream until the sand bar is broken, usually by the first heavy rains. Although the formation of a sand bar may temporarily act as a migration barrier, it does not represent a reproductive isolation mechanism.

The timing of coho salmon spawning runs may be partly genetically based, but it is also subject to modification by streamflow, water temperature, and other environmental variables. Data from other river systems indicate that the timing of spawning migrations are generally attributed to the increase of stormflow runoff (usually occurring earlier in the northern range of coho salmon populations), which allows the salmon to migrate through the lagoons/estuaries and higher up the river systems to their natal tributaries. Since the earlier studies of the 1930's and 1940's, there has been an apparent shift in peak spawning migration timing within Scott and Waddell Creeks to several weeks later in the season. Spawning migrations in most California coastal streams and rivers have shifted to later in the spawning season, possibly due to degraded conditions within the watersheds, rivers, and estuaries. The loss of large woody debris within stream systems which helps flush out sediment and creates deep holding pools, excessive diversion of drought limited flows which increases water temperatures, and the reduction in area and volume of most estuaries and rivers due to filling with sediment, may have created conditions in which coho salmon can no longer access or survive in rivers until the start of heavy winter rains. Although other explanations are possible, the year to year variation in the timing of coho spawning migrations in Scott and Waddell Creeks are similar and within the range of run times reported for other coho salmon populations in California and Oregon. The modest difference in peak spawn timing cited by the petitioner may reflect (or may be the result

Table 2. Scott Creek Egg Taking History and Estimated Number of Adult Spawners Used from 1908-1940. (Streig 1991)

Year	Species	# Green Eggs	Estimated[a] # Females	Estimated[b] Total #
1905-1907	No Data			
1908	Steelhead	725,000	145	290
	Coho	None Spawned		
1909	Steelhead	2,182,000	437	874
	Coho	1,400,000	518	1036
1910	Steelhead	2,709,300	542	1084
	Coho	None Spawned		
1911-1914	No Data			
1915	Steelhead	3,357,000	672	1344
	Coho	None Spawned		
1916	Steelhead	3,111,000	632	1264
	Coho	None Spawned		
1917	Steelhead	2,250,000	450	900
	Coho	None Spawned		
1918	Steelhead	3,900,000	780	1560
	Coho	None Spawned		
1919	Steelhead	3,900,000	780	1560
	Coho	None Spawned		
1920	Steelhead	1,060,000	212	424
	Coho	None Spawned		
1921	Steelhead	4,200,000	840	1680
	Coho	None Spawned		
1922-1923	No Data			
1924	Steelhead	2,590,000	518	1036
	Coho	None Spawned		
1925	Steelhead	3,000,000	600	1200
	Coho	None Spawned		
1926	Stealhead	1,300,000	260	520
	Coho	None Spawned		

other California coho salmon populations, as well as the effects of hatchery influence on these populations. Distinctive differences in habitat characteristics included spawning in habitats characterized by highly mobile sediment bedloads and extreme hydrological cycles. Distinctive life history characteristics included the reduced number of eggs produced by female coho salmon that spawn in Scott and Waddell Creeks.

Many of the habitat characteristics and life history traits exhibited by coho salmon in Scott and Waddell Creeks are found in other coho salmon populations in California. Many of the streams and rivers in California exhibit similar elevated summer/fall water temperatures and extreme winter-flow bedload movements and hydrologic cycles. The extreme hydrologic cycles and resultant bedload movement found in Scott and Waddell Creeks undoubtedly affect the success of early spawning coho salmon in these watersheds, however, these conditions are very similar to those found in most of California's coastal streams and rivers. Excessive use of drought limited flows in Scott and Waddell Creeks, as well as other systems, has probably exacerbated the problems of poor land use management and stream habitat conditions.

We have no data to indicate that Scott and Waddell Creeks coho salmon egg production is related to the smaller average size of these fish in comparison to other coastal coho salmon populations. The number of eggs produced by a female coho salmon, in and by itself, does not indicate that there are differences between populations from other watersheds. Each river system is highly variable in year to year production and a smaller size of adult spawner may result from the overharvesting of larger individuals. The number of eggs produced by Scott Creek and Waddell Creek coho salmon were within the range reported from other coho salmon populations along the entire west coast.

NMFS found some records of hatchery releases of other coho salmon stocks into Scott and Waddell Creeks, as well as most of the central California coastal streams, from the early 1900's through the early 1970's. The limited number off fish stocking records indicated that Scott and Waddell Creeks were planted with approximately a total of 500,000 and 130,000 coho salmon fry and juveniles, respectively, from numerous other watersheds. More than 2,000,000 coho salmon fry and juveniles have been planted in Santa Cruz County streams with coho salmon stocks from Washington, Oregon, and northern California. The magnitude (and likely effect) of early coho salmon fry releases was probably fairly small. However, starting in the 1950's extensive juvenile coho salmon plants began. Even though Scott and Waddell Creeks have not been planted with outside sources of coho salmon since the early to mid-1970's, the effects of continuous hatchery plants prior to that time may have affected any distinctive phenotypic and life history traits that originally existed in these populations.

After a thorough analysis of all information available, NMFS has determined that the Scott and Waddell Creeks coho salmon populations do not represent a "species" under the ESA, and therefore, a proposal to list these populations under the ESA is not warranted at this time. However, these populations may be part of a larger ESU whose extent has not yet been determined. Whether this larger ESU merits protection under the ESA cannot be determined at this time. NMFS will attempt to identify the larger ESU that contains the Scott and Waddell Creeks coho salmon populations as part of the ongoing status review that is addressing all coastal coho salmon populations in California, Oregon, Washington, and Idaho.

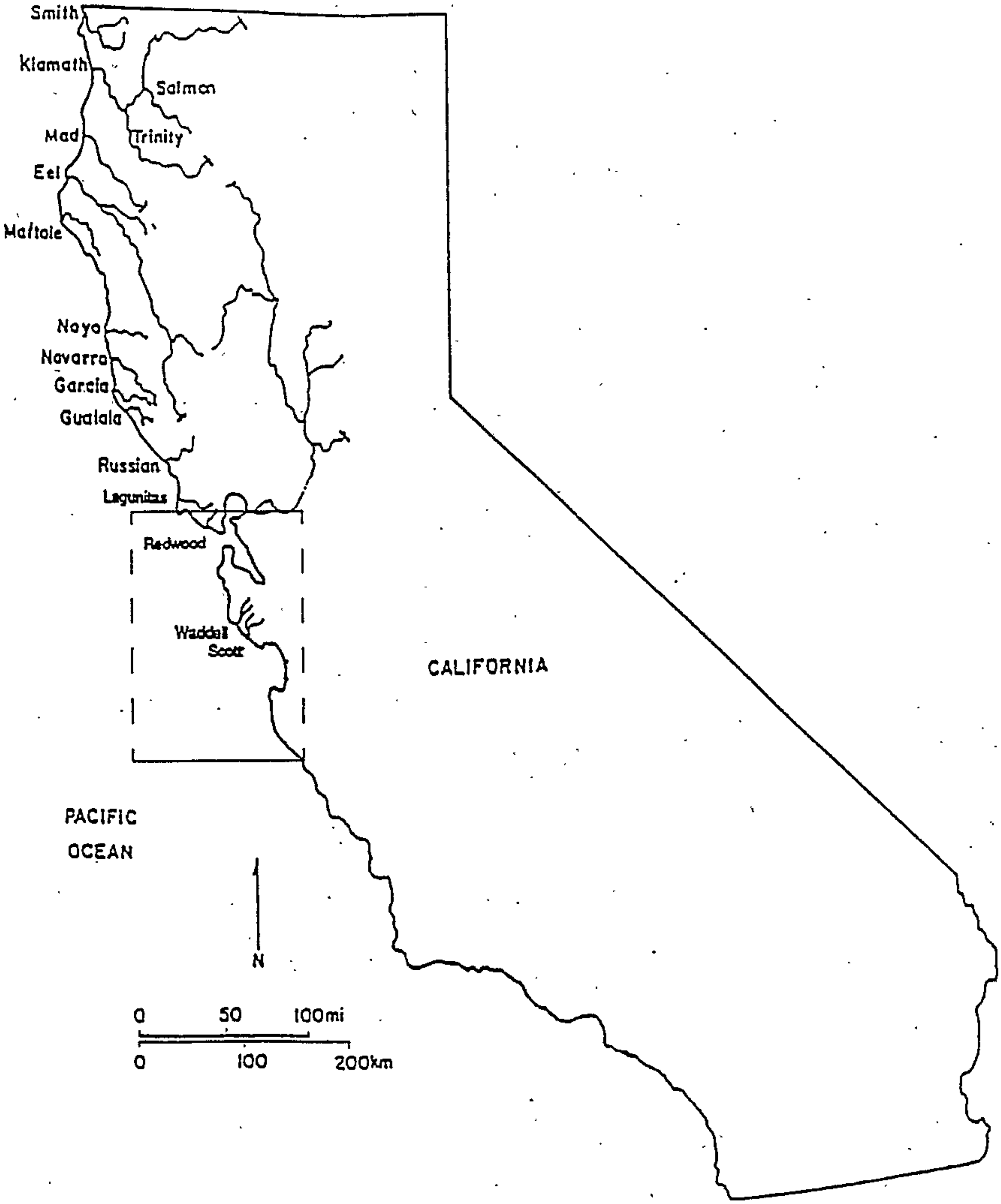

Figure 1 Location map of Scott Creek and Waddell Creek, Santa Cruz County, California.

Table 1. History of Fish Plantings from 1909 through 1941 in Santa Cruz County, California. (individual hatcheries listed have their own history of stock transfers)

Year	Species	# Fish	Location of Plant	Origin[a]
1905-1908	No Data			
1909	Steelhead	862,000	Santa Cruz Co.	
	Coho	600,000	Santa Cruz Co.	
1910	Steelhead	753,500	Santa Cruz Co.	
	Coho	No Data		
1911	No Data			
1912	Steelhead	803,500	Santa Cruz Co.	
	Coho	No Data		
1913	Steelhead	121,000	Scott Creek	
		24,000	Waddell Creek	
		493,000	Santa Cruz Co.	
	Coho	15,000	Waddell Creek	Sisson
		25,000	Scott Creek	Sisson
	Chinook	294,600	San Lorenzo River	Sisson
1914	No Data			
1915	Steelhead	22,000	Waddell Creek	
		148,000	Scott Creek	
		485,000	Santa Cruz Co.	
	Coho	25,000	Scott Creek	Sisson
		18,000	Waddell Creek	Sisson
		28,000	San Lorenzo River	Sisson
1916	Steelhead	877,000	Santa Cruz Co.	
	Coho	No Data		
1917	Steelhead	500,000	Santa Cruz Co.	
	Coho	25,000	Santa Cruz Co.	Sisson
1918	Steelhead	710,000	Santa Cruz Co.	
	Coho	No Data		
	Chinook	135,000	San Lorenzo River	Mt. Shasta[b]
1919	Steelhead	535,000	Santa Cruz Co.	
	Coho	No Data		
1920	No Data			

(Table 1. continued)

Year	Species	# Fish	Location of Plant	Origin[a]
1921	Steelhead	500,000	Santa Cruz Co.	
	Coho	No Data		
1922-1923	No Data			
1924	Steelhead	500,000	Santa Cruz Co.	
	Coho	No Data		
1925	Steelhead	1,295,000	Santa Cruz Co.	
	Coho	No Data		
1926	Steelhead	903,000	Santa Cruz Co.	
	Coho	No Data		
1927	No Data			
1928	Steelhead	25,000	San Lorenzo River	
Furunculosis kills Big Creek Hatchery stock; 25,000 survived Brookdale Hatchery				
	Steelhead	152,000	Santa Cruz Co.	Mt. Shasta
	Coho	No Data		
1929	Steelhead	391,000	Santa Cruz Co.	
	Coho	25,000	Scott Creek	
		22,700	Waddell Creek	
		233,500	San Lorenzo River	
1930	Steelhead	506,000	Santa Cruz Co.	
	Coho	36,700	Scott Creek	
		30,000	Waddell Creek	
		27,625	Pajaro River	
		9,000	Soquel Creek	
		54,750	San Lorenzo River	
		50,000	San Lorenzo River	Ft. Seward
1931	No Data			
1932	Steelhead	630,000	Santa Cruz Co.	
	Coho	15,000	Scott Creek	Ft. Seward
		10,500	San Lorenzo River	Ft. Seward
		6,500	Soquel Creek	Ft. Seward
	Atlantic Salmon	1,500	Scott Creek	Mt. Shasta

(Table 1. continued)

Year	Species	# Fish	Location of Plant	Origin[a]
1933	Steelhead	307,928	Santa Cruz Co.	
	Coho	18,592	Scott Creek	Prairie Creek
		16,005	Waddell Creek	Prairie Creek
		21,030	San Lorenzo River	Prairie Creek
1934	Steelhead	260,611	Santa Cruz Co.	
	Coho	15,020	Scott Creek	
		12,730	Soquel Creek	
		12,345	San Lorenzo River	
		50,000	San Lorenzo River	Prairie Creek
1935	Steelhead	922,492	Santa Cruz Co.	
	Coho	10,000	Scott Creek	Prairie Creek
		22,025	San Lorenzo River	Prairie Creek
1936	Steelhead	766,070	Santa Cruz Co.	
	Coho	5,248	Scott Creek	
		40,095	San Lorenzo River	
1937	Steelhead	1,076,322	Santa Cruz Co.	
	Coho	81,275	Scott Creek	
		44,710	San Lorenzo River	
	Chinook	22,164	San Lorenzo River	Mt. Shasta
1938	Steelhead	872,742	Santa Cruz Co.	
	Coho	77,060	Scott Creek	
		40,840	Soquel Creek	Prairie Creek
		45,800	San Lorenzo River	Prairie Creek
1939	Steelhead	749,546	Santa Cruz Co.	
	Coho	53,518	Scott Creek	
		18,900	San Vicente Creek	
		50,000	Soquel Creek	
1940	Steelhead	311,777	Santa Cruz Co.	
	Coho	No Data		
1941	Steelhead	328,765	Santa Cruz Co.	Prairie Creek
	Coho	14,685	San Lorenzo River	Prairie Creek
1942	Brookdale was shutdown			

[a] If no hatchery is listed, fish are Scott Creek stock from either Big Creek or Brookdale Hatchery.

[b] Sisson Hatchery name changed to Mount Shasta Hatchery.

Table 2. Scott Creek Egg Taking History and Estimated Number of Adult Spawners Used from 1908-1940. (Streig 1991)

Year	Species	# Green Eggs	Estimated[a] # Females	Estimated[b] Total #
1905-1907	No Data			
1908	Steelhead	725,000	145	290
	Coho	None Spawned		
1909	Steelhead	2,182,000	437	874
	Coho	1,400,000	518	1036
1910	Steelhead	2,709,300	542	1084
	Coho	None Spawned		
1911-1914	No Data			
1915	Steelhead	3,357,000	672	1344
	Coho	None Spawned		
1916	Steelhead	3,111,000	632	1264
	Coho	None Spawned		
1917	Steelhead	2,250,000	450	900
	Coho	None Spawned		
1918	Steelhead	3,900,000	780	1560
	Coho	None Spawned		
1919	Steelhead	3,900,000	780	1560
	Coho	None Spawned		
1920	Steelhead	1,060,000	212	424
	Coho	None Spawned		
1921	Steelhead	4,200,000	840	1680
	Coho	None Spawned		
1922-1923	No Data			
1924	Steelhead	2,590,000	518	1036
	Coho	None Spawned		
1925	Steelhead	3,000,000	600	1200
	Coho	None Spawned		
1926	Stealhead	1,300,000	260	520
	Coho	None Spawned		

(Table 2. continued)

Year	Species	# Green Eggs	Estimated[a] # Females	Estimated[b] Total #
1927-1928	No Data			
1929	Steelhead	4,167,000	834	1668
	Coho	298,000	111	222
1930	Steelhead	4,167,000	278	556
	Coho	134,000	50	100
1931	No Data			
1932	Steelhead	2,025,000	405	810
	Coho	None Spawned		
1933	Steelhead	1,225,000	245	490
	Coho	None Spawned		
1934	Steelhead	808,000	162	324
	Coho	124,000	46	92
1935	Steelhead	1,987,000	398	796
	Coho	None Spawned		
1936	Steelhead	1,777,500	356	712
	Coho	64,000	24	48
1937	Steelhead	1,711,000	343	686
	Coho	148,000	55	110
1938	Steelhead	1,545,000	309	618
	Coho	97,500	36	72
1939	Steelhead	1,745,000	349	698
	Coho	207,000	77	154
1940	Steelhead	418,000	84	168
	Coho	None Spawned		

Big Creek Hatchery and Scott Creek fish trap destroyed by flood.

[a] Estimated # of females (Steelhead averaged 5,000 eggs and Coho averaged 2,700 eggs per female as reported by Shapovalov and Taft 1954)

[b] Estimated total number of adults used for egg production (average sex ratio of 1:1 male/female as reported by Shapovalov and Taft 1954)

Table 3. History of Fish Plantings by SilverKing Oceanic Farms (SKOF) in Davenport Landing Creek from 1980 through 1988, Santa Cruz County, California.

Year	Species	Brood Year	Orgin of Stock	Total Releases
1980	Steelhead	1978	Whale Rock Reservoir	235
	Coho	1978	Univ. of Washington	100,000
		1979	Univ. of Washington	29,497
		1979	Cowlitz River	21,818
		1979	Univ. of Washington X Klamath River	33,989
		1979	SKOF	59,781
	Chinook	1979	Bonneville	38,000
		1979	Univ. of Washington	136,338
1981	Steelhead	1980	Whale Rock Reservoir	1,030
	Coho	1979	SKOF	49,401
		1979	Univ. of Washington X Klamath River	21,500
		1979	Univ. of Washington	3,383
		1979	Alsea River	81,840
		1980	SKOF	5,333
		1980	Univ. of Washington	64,255
		1980	Toutle River	15,378
		1980	Oregon Aquaculture	11,062
		1980	Cowlitz River	13,191
		1980	Miscellaneous stocks	3,150
	Chinook	1979	Univ. of Washington	4,000
		1980	Univ. of Washington	1,153
1982	Steelhead	1981	SKOF	453
	Coho	1980	SKOF	2,371
		1980	Cowlitz River	2,800
		1980	Univ. of Washington	4,650
		1981	Noyo River	15,304
		1981	Univ. of Washington	77,743
	Chinook	1980	Univ. of Washington	355,900
		1981	Univ. of Washington	203,149
		1982	Univ. of Washington	137,021
1983	Steelhead	1981	SKOF	16,579
		1982	SKOF	2,619
	Coho	1982	SKOF	17,959
		1982	Noyo River	8,000
	Chinook	1982	SKOF	37,050
1984	Steelhead	1984	Dry Creek	35,777
	Coho	1983	SKOF	201,824
		1983	Univ. of Washington	95,625
	Chinook	1983	SKOF	14,014

cont. Table 3.

Year	Species	Brood Year	Origin of Stock	Total Releases
1985	Steelhead	1983	SKOF	121,000
	Coho	1984	SKOF	63,000
	Chinook	1984	SKOF	51,225
1986	Steelhead	1984	SKOF	41,250
	Coho	1985	SKOF	102,520
	Chinook	1985	SKOF	502
1987	Steelhead	1985	SKOF	65,000
	Coho	1986	SKOF	10,000
	Chinook	1986	SKOF	19,500
1988	Steelhead	1986	SKOF	211,000
	Coho	1987	SKOF	2,400
	Chinook	No Plants		

1989 SKOF no longer in operation.

Table 4. History of Fish Plantings by the Monterey Bay Salmon and Trout Project and California Department of Fish and Game in Central California Coastal Watersheds from 1978 through 1993 (includes smolt, fingerling, and fry, plants).

Year	Species	# Fish	Location of Plant	Origin of Stock
1978	Steelhead	No Data		
	Coho	1,500	Monterey Bay	Ten Mile River
1979	Steelhead	No Data		
	Coho	8,800	Monterey Bay	Noyo River
1980	Steelhead	No Data		
	Coho	9,540	Monterey Bay	Noyo River
1981	Steelhead	17,040	Pajaro River	Mad River
	Coho	No Data		
1982	Steelhead	20,385	San Lorenzo River	Mad River
		22,650	Pajaro R.	Mad River
	Coho	No Data		
1983	No Data			
1984	Steelhead	13,500	San Lorenzo River	Carmel River
		26,625	San Lorenzo River	Russian River
		4,900	Big Creek	Carmel River
		3,260	Big Creek	Scott Creek
		41,277	Carmel River	Carmel River
		12,375	Soquel Creek	Carmel River
		7,500	Soquel Creek	Russian River
		8,200	Pajaro River Tribs.	Carmel River
		17,000	Parjaro River	Russian River
	Coho	17,160	San Lorenzo River	Russian River
1985	Steelhead	24,586	San Lorenzo River	Russian River
		3,835	Big Creek	Scott Creek
		9,604	Soquel Creek	Russian River
		6,750	Pajaro River	Russian River
		5,145	Uvas Creek	Russian River
		5,635	Arroyo Seco River	Russian River
	Coho	428	Big Creek	Scott Creek
1986	Steelhead	28,900	San Lorenzo River	Scott Creek
		9,200	Big Creek	Scott Creek
		6,000	Soquel Creek	Scott Creek
		7,800	Uvas Creek	Scott Creek
		5,200	Llagas Creek	Scott Creek
		7,000	Corralitos Creek	Scott Creek
		12,500	Arroyo Seco River	Scott Creek

(cont. Table 4)

Year	Species	# Fish	Location of Plant	Origin of Stock
1986	Coho	15,860	San Lorenzo River	Noyo River
1987	Steelhead	53,890	San Lorenzo River	Scott Creek
		9,212	Big Creek	Scott Creek
		21,450	Soquel Creek	Scott Creek
		28,600	Pajaro River	Scott Creek
		5,200	Arroyo Seco River	Scott Creek
	Coho	No Plants		
1988	Steelhead	35,746	San Lorenzo River	Scott Creek
		1,000	Scott Creek	Scott Creek
		17,970	Soquel Creek	Scott Creek
		5,700	Pajaro River	Scott Creek
		10,840	Uvas Creek	Scott Creek
		5,000	Corralitos Creek	Scott Creek
		3,000	Browns Creek	Scott Creek
		12,040	Branciforte Creek	Scott Creek
		4,500	Salinas River	Scott Creek
	Coho	20,822	San Lorenzo River	Noyo River
		5,997	San Lorenzo River	Scott Creek
		2,450	Scott Creek	Scott Creek
1989	Steelhead	37,245	San Lorenzo River	Scott Creek
		4,930	Scott Creek	Scott Creek
		1,000	Sempervirons Res.	Scott Creek
		11,620	Soquel Creek	Scott Creek
		14,700	Pajaro River	Scott Creek
	Coho	25,362	San Lorenzo River	Noyo River
		2,756	Scott Creek	Scott Creek
1990	Steelhead	53,645	San Lorenzo River	San Lorenzo R.
		8,715	San Lorenzo River	Scott Creek
		7,611	Scott Creek	Scott Creek
		1,000	Sempervirons Res.	Scott Creek
		14,710	Soquel Creek	San Lorenzo R.
		5,590	Soquel Creek	Scott Creek
		19,866	Pajaro River	San Lorenzo R.
	Coho	34,500	San Lorenzo River	Prairie Creek
		6,552	Scott Creek	Scott Creek
1991	Steelhead	47,112	San Lorenzo River	San Lorenzo R.
		19,048	San Lorenzo River	Scott Creek
		9,745	Scott Creek	Scott Creek
		18,080	Soquel Creek	San Lorenzo R.
		11,150	Pajaro River	San Lorenzo R.
		6,650	Corralitos Creek	San Lorenzo R.
		15,345	Salinas River	San Lorenzo R.
		16,955	Carmel River	Carmel River

(cont. Table 4)

Year	Species	# Fish	Location of Plant	Origin of Stock
1991	Coho	19,880	San Lorenzo River	San Lorenzo R.
		5,040	San Lorenzo River	Scott Creek
		5,460	Scott Creek	Scott Creek
1992	Steelhead	60,861	San Lorenzo River	San Lorenzo R.
		7,502	Scott Creek	Scott Creek
		11,648	Soquel Creek	San Lorenzo R.
		10,509	Pajaro River	San Lorenzo R.
		7,728	Uvas Creek	San Lorenzo R.
		230	Tar Creek	San Lorenzo R.
		506	Little Arthur Creek	San Lorenzo R.
		5,115	Corralitos Creek	San Lorenzo R.
		828	Pescadero Creek	San Lorenzo R.
		10,090	Salinas River	San Lorenzo R.
		102,777	Carmel River	Carmel River
	Coho	1,872	San Lorenzo River	San Lorenzo R.
1993	Steelhead	34,377	San Lorenzo River	San Lorenzo R.
		3,360	San Lorenzo River	Scott Creek
		10,070	Scott Creek	Scott Creek
		12,224	Soquel Creek	Scott Creek
		4,770	Pajaro River	San Lorenzo R.
		5,970	Uvas Creek	San Lorenzo R.
		3,350	Bean Creek	San Lorenzo R.
		1,241	Little Arthur Creek	San Lorenzo R.
		1,095	Bodfish Creek	San Lorenzo R.
		6,570	Corralitos Creek	Scott Creek
		2,940	San Vicente Creek	Scott Creek
		8,020	Arroyo Seco River	San Lorenzo R.
		9,812	Carmel River	Carmel River
	Coho	11,808	San Lorenzo River	San Lorenzo R.
		1,860	Scott Creek	Scott Creek

Table 5. Total Number of Commercial and Recreational Landings of Coho Salmon in San Francisco Bay and Monterey Bay Ports, California. (1952-1965 reported by Jensen and Startzell 1967; 1976-1992 reported by Pacific Fishery Management Council 1993)

	San Francisco Bay		Monterey Bay	
Year	Commercial	Recreational	Commercial	Recreational
1952	928	No Data	158	No Data
1953	5,031	No Data	651	No Data
1954	1,322	No Data	461	No Data
1955	2,041	No Data	648	No Data
1956	1,626	No Data	251	No Data
1957	9,235	No Data	4,139	No Data
1958	3,564	No Data	324	No Data
1959	5,874	No Data	95	No Data
1960	4,503	No Data	178	No Data
1961	8,847	No Data	413	No Data
1962	1,503	41	255	0
1963	23,680	1,335	2,389	163
1964	47,912	8,322	12,491	6,225
1965	14,494	2,961	2,692	1,024
1966-1975 No Data				
1976-1980	20,800	3,600	9,400	100
1981-1985	7,700	1,100	1,400	100
1986	5,100	400	1,300	< 50
1987	1,200	100	100	< 50
1988	6,700	300	400	< 50
1989	6,500	900	500	< 50
1990	27,400	5,800	5,700	1,200
1991	53,000	7,700	21,400	2,900
1992	300	1,600	1,900	200

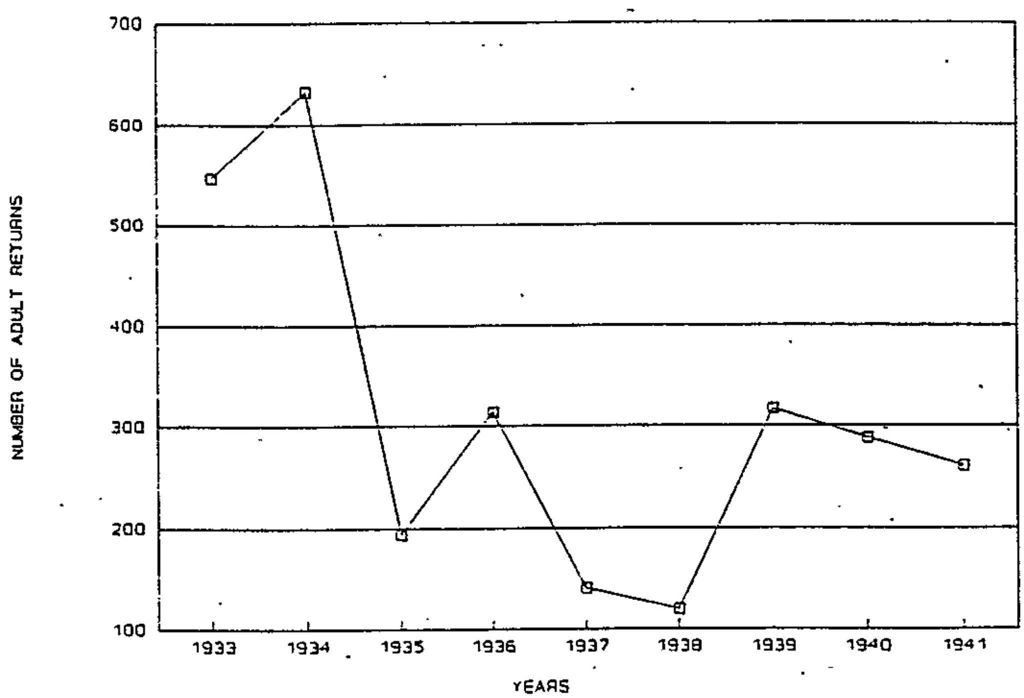

Figure 2. Numbers of adult coho salmon in Waddell Creek, California, 1933-1941 (Shapovalov and Taft 1954).

Table 6. Number of Adult Coho Salmon Trapped by Monterey Bay Salmon and Trout Project and California Department of Fish and Game in Scott Creek, California. (1984-1993)

Year	Number of Males	Number of Females	Number of Grilse	Total Number
1984	1	3		4
1985	4	0		4
1986	1	0		1
1987	11	22		33
1988	4	6		10
1989	10	0		10
1990	63	35		96
1991	2	0		2
1992	9	1*	23	33
1993	24	40		64

* trapped in the San Lorenzo River

Table 7. Number of Adult Coho Salmon Trapped by Monterey Bay Salmon and Trout Project and California Department of Fish and Game in the San Lorenzo River, California. (1987-1993)

Year	Number of Males	Number of Females	Number of Grilse	Total Number
1987	36	11		47
1988	19	36		55
1989	26	4		30
1990	115	68		183
1991	6	17		23
1992	17	13	16	46
1993	14	11		25

Table 8. List of twenty-one enzymes, (Enzyme Commission (E.C.) numbers, number of loci scored, and enzyme abbreviations) to electrophoretically survey coho salmon in California by Bartley (1987).

Enzyme	E.C. Number	Number of Loci	Enzyme Abbreviation
Aspartate aminotransferase	2.6.1.1	3	AAT
Aconitate hydratase	4.2.1.3	1	AH
Alcohol dehydrogenase	1.1.1.1	1	ADH
Adenylate kinase	2.7.4.3	2	AK
Aldolase	4.1.2.13	1	FBALD
Creatine kinase	2.7.3.2	5	CK
β-N-Acetyl-D-galactosaminidase	3.2.1.53	1	βGALA
Glycerophosphate dehydrogenase	1.1.1.8	2	GPDH
Glucose phosphate isomerase	5.3.1.9	3	GPI
L-Iditol dehydrogenase	1.1.1.14	2	IDDH
Isocitrate dehydrogenase	1.1.1.42	4	IDH
Lactate dehydrogenase	1.1.1.27	5	LDH
Malate dehydogenase	1.1.1.37	4	MDH
Mannose phosphate isomerase	5.3.1.8	1	MPI
6-Phospho-gluconate dehydrogenase	1.1.1.44	1	PGDH
Phospho-glycerate kinase	2.7.2.3	1	PGK
Phosphoglucomutase	2.7.5.1	2	PGM
Super-oxide dismutase	1.15.1.1	1	SOD
Transferrin	serum protein	1	TFN
Peptidase substrates			
A glycl-leucine	3.4.11/3.4.13	2	PEPA PEPC
D phenylalanyl-L-proline	3.4.11/3.4.13	1	PEPD
B leucyl-glycyl-glycine		1	PEPB

Table 9. Collection sites for twenty-seven groups of coho salmon in California (Bartley 1987). Groups are listed individually south to north followed by their approximate location; N=the number of individuals tested in each group.

Location	N
Scott Creek- Santa Cruz Co.	39
Waddell Creek- Santa Cruz Co.	10
Laguntas Creek- Tomales Bay	32
Tanner Creek- Salmon Creek	62
Willow Creek- Russian River	38
Flynn Creek- N. Fork Navarro River	23
John Smith Creek- N. Fork Navarro River	15
Albion River- Mendocino Co.	30
Little River- Mendocino Co.	51
Twolog Creek- Big River	23
Russian Gulch- Mendocino Co.	31
Casper Creek- Mendocino Co.	82
Hare Creek- Mendocino Co.	28
Little N. Fork Noyo- N. Fork Noyo River	20
Kass Creek- S. Fork Noyo River	17
Pudding Creek- Mendocino Co.	47
Little N. Fork Ten Mile Creek- N. Fork Ten Mile River	22
Cottoneva Creek- Mendocino Co.	28
Huckleberry Creek- S. Fork Eel River	52
Butler Creek- S. Fork Eel River	30
Redwood Creek- S. Fork Eel River	29
Elk River- Humboldt Bay	30
Prairie Creek- Humboldt Co.	3
Rush Creek- Trinity River	7
Trinity Hatchery- Trinity River	111
Deadwood Creek- Trinity River	26
West Branch Mill Creek- Smith River	30

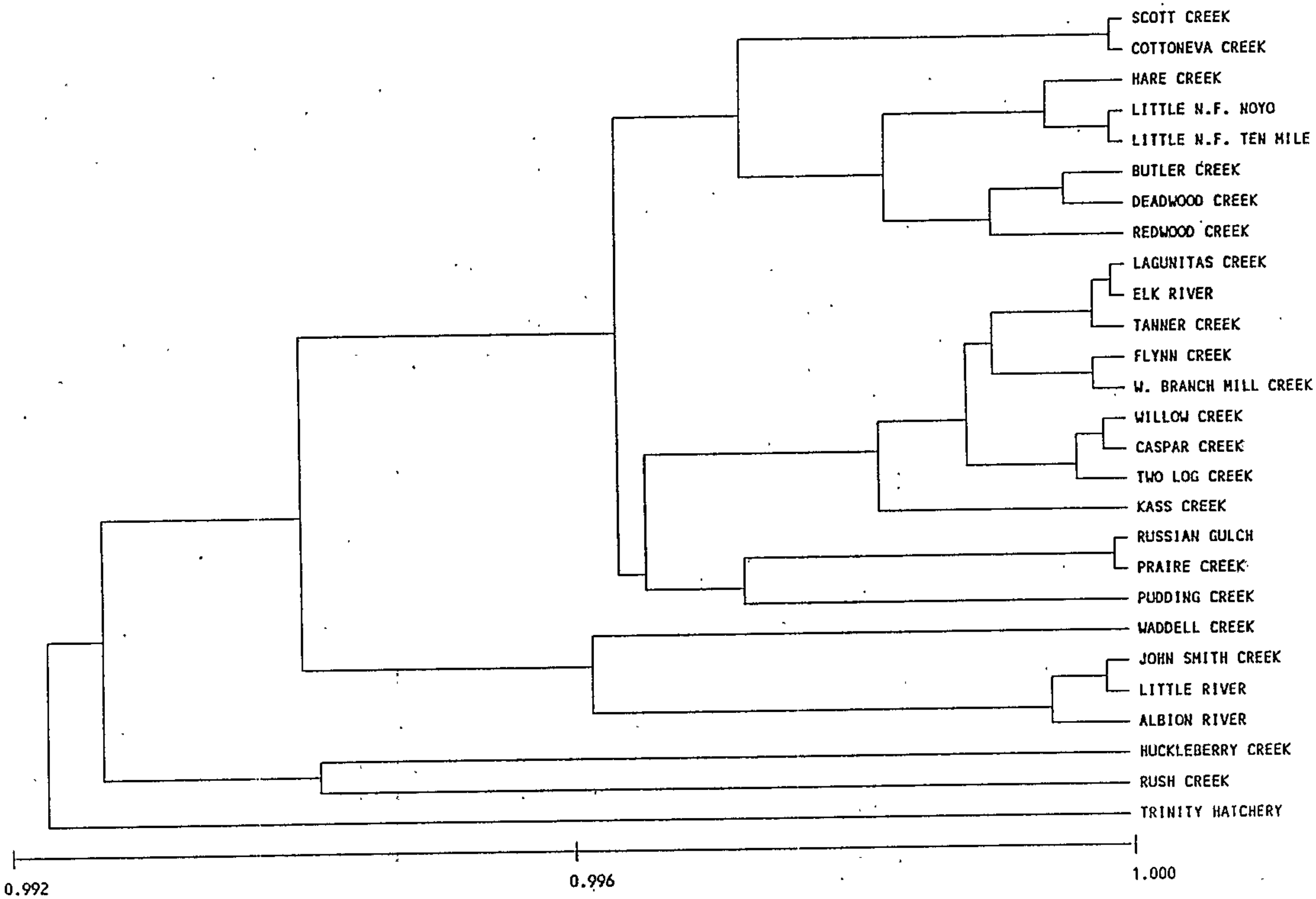

Figure 3. Dendogram based on Nei's (1978) genetic identities between twenty-seven groups of coho salmon (Bartley 1987).

Table 10. Twenty-three loci used for 27 samples of coho salmon from California (Bartley 1987).

Locus	Number of Samples with Data Sets	Number of Samples Polymorphic	Range of Common Allele Frequencies	Number of Alleles
AAT-2	21	3	1.000 - 0.865	2
AAT-3	19	3	1.000 - 0.912	2
AH	24	2	1.000 - 0.826	3
CK-2	26	2	1.000 - 0.644	2
CK-3	26	3	1.000 - 0.800	2
βGALA	22	2	1.000 - 0.625	2
GPI-2	27	5	1.000 - 0.875	3
GPI-3	27	7	1.000 - 0.643	4
IDDH-1	22	5	1.000 - 0.912	2
IDH-1	22	2	1.000 - 0.750	2
IDH-2	22	9	1.000 - 0.563	2
IDH-3	27	8	1.000 - 0.621	4
IDH-4	27	7	1.000 - 0.750	4
LDH-3	23	3	1.000 - 0.966	2
LDH-4	27	4	1.000 - 0.871	2
MDH-3	26	15	1.000 - 0.700	3
MPI	22	1	1.000 - 0.924	3
PGDH	24	2	1.000 - 0.949	2
PGM-1	24	18	1.000 - 0.630	2
TFN	18	17	1.000 - 0.500	4
PEPA	26	5	1.000 - 0.864	4
PEPC	20	17	1.000 - 0.265	3
PEPD	12	5	1.000 - 0.850	3

Table 11. Average heterozygosity (H) estimates for twenty-seven groups of coho salmon in California (Bartley 1987).

Group	Number of Loci Scored	H
Scott Creek	35	0.000
Waddell Creek	40	0.050
Laguntas Creek	35	0.024
Tanner Creek	43	0.020
Willow Creek	33	0.014
Flynn Creek	44	0.035
John Smith Creek	42	0.034
Albion River	45	0.038
Little River	42	0.031
Twolog Creek	44	0.042
Russian Gulch	41	0.022
Casper Creek	45	0.034
Hare Creek	44	0.033
Little N. Fork Noyo River	42	0.026
Kass Creek	44	0.039
Pudding Creek	44	0.032
Little N. Fork Ten Mile Creek	45	0.026
Cottoneva Creek	44	0.009
Huckleberry Creek	44	0.042
Butler Creek	44	0.026
Redwood Creek	44	0.027
Elk River	34	0.008
Prairie Creek	43	0.042
Rush Creek	32	0.014
Trinity Hatchery	44	0.039
Deadwood Creek	40	0.008
West Branch Mill Creek	39	0.016
Average H		0.027

LITERATURE CITED

Allen, J.T. 1958. Report of first season's operations, 1957-1958, Pudding Creek silver salmon egg collecting station, Mendocino County, California Department of Fish and Game Inland Fisheries Administration Report 58-12.

Allendorf, F.W. and F.M. Utter. 1979. Population genetics, Pp. 407-454, In W.S. Hoar, D.J. Randall, and J.R. Brett (ed). Fish Physiology, Volume 8. Academic Press, New York.

Baker, P. and F. Reynolds. 1986. Life history, habitat requirements, and status of coho salmon in California. Report to the California Fish and Game Commission.

Banks, J.W. 1969. A review of the literature on upstream migration of adult salmonids. Journal of Fisheries Biology. 1:85-136.

Bartley, D.M., B. Bentley, P.G. Olin, and G. A.E. Gall. 1992. Population genetic structure of Coho salmon (Oncorhynchus kisutch) in California. California Department of Fish and Game 78(3):88-104.

Bartley, D.M. 1987. The genetic structure of chinook and coho salmon populations in California, with a note on the genetic variability in sturgeon (Acipenseridae). Ph.D. Thesis, Univ. California Davis, California. 204 pp.

Berger, J. (ed.) 1982. Anadromous salmonid genetic resources: an assessment and plan for California. California Gene Resources Program. National Council of Gene Resources, Berkeley. 149 pp.

Brannon, E.L. 1981. Orientation mechanisms of homing salmonids. Pp. 217-219, In E.L. Brannon and E.O. Salo, (ed). Salmon and trout migratory behavior symposium. Univ. of Washington, Seattle.

Bratovich, P.M. and D.W. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California. Vol. I. Prepared for Marin Municipal Water District, Corte Madera, California.

Brown, L.R. and P.B. Moyle. 1991. Status of coho salmon in California. Report to the National Marine Fisheries Service, Submitted July 1991. 114 pp.

California Advisory Committee on Salmon and Steelhead Trout. 1988. Restoring the balance, 1988 annual report. Annual report to the California Department of Fish and Game and California Legislature.

California Department of Fish and Game. 1991. Sport fishing for anadromous salmonid fishes. California Department of Fish and Game draft Environmental/Satellite Document. August 1991.

---------------------------------------. 1992. Status Report: California salmon. A report to the Fish and Game Commission, California Department of Fish and Game, Sacramento, California. 34 pp.

---------------------------------------. 1993. Memo to ESA Administrative Record for Scott Creek coho salmon re: Fish disease history of Scott Creek and the San Lorenzo River coho salmon. Memo dated November 12, 1993, 1 p. and enclosures.

California Division of Mines and Geology (CDMG). 1992. Geology, slope stability, and earthquake damage in Soquel Demonstration State Forest. CDMG, Sacramento, California. 54 pp.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal Fisheries Research Board Canada. 19:1047-1080.

Cox, B. 1992. Proposal to inject erythromycin into adult female coho salmon for control of bacterial kidney disease (BKD). Submitted to ESA Administrative Record for Scott Creek coho salmon. California Department of Fish and Game, Fish Disease Laboratory, Rancho Cordova, California.

Cox, Bill. Personal Communication. California Department of Fish and Game, Sebastopol, California.

Elliot, D.G., R.L. Pascho, and G.L. Bullock. 1989. Developments in the control of bacterial kidney disease of salmonid fishes. Diseases of Aquatic Organisms 6:210-215.

Evelyn, T.P.T., L. Prosperi-Porta, and J.E. Ketcheson. 1986. Experimental intra-ovum infection of salmonid eggs with Renibacterium salmoninarum and vertical transmission of the pathogen with such eggs despite their treatment with erythromycin. Diseases of Aquatic Organisms 1:197-202. Behavioral Ecology Sociobiology. 16:65-71.

Fraidenburg, M.E., M.A. Hunter, A.J.M. Stohr, and P.L. Pattillo. 1985. The ocean journeys of Pacific Northwest chinooks and cohos, and steelheads. Pp. 109-126, In R.H. Stroud, (ed).

Proceedings of the tenth annual marine recreational fisheries symposium. National Coalition for Marine Conservation, Inc., Savannah, Georgia.

Fraser, F.J. 1969. Population density effects on survival and growth of juvenile coho salmon and steelhead trout in experimental stream channels. Pp. 253-268, In T.G. Northcote (ed), Symposium on trout and steelhead in streams. Institute of Fisheries, University of British Columbia, Vancouver.

Fraser, F.J., E.A. Perry, and D.T. Lightly. 1983. Big Qualicum River salmon development project. Volume 1: A biological assessment 1959-1972. com. tech. Rep. fish. Aquat. Sci. 1189:198p.

Fry, D.H., Jr. 1936. Life history of Hesperoleucus venustus. California Fish and Game 22:65-98.

-------------. 1960. King salmon and silver salmon. Pp. 41-46, In California ocean fisheries resources to the year 1960. California Department of Fish and Game, Sacramento, California.

-------------. 1973. Anadromous fishes of California. California Department of Fish and Game 22:65-98.

Gall, G.A.E. 1993. Memo to ESA Administrative Record for Scott and Waddell Creeks coho salmon re: coho salmon genetics information. Memo dated November 29, 1993, 1 p. and enclosures.

Hallock, R.J. and D.H. Fry, Jr. 1967. Five species of salmon, Oncorhynchus, in the Sacramento River, California. California Department of Fish and Game 53:5-22.

Hasler, A.D. and A.T. Scholz. 1983. Olfactory imprinting and homing in salmon. Spring-Verlag, Berlin, Germany. 134 pp.

Hasler, A.D. and W.J. Wisby. 1951. Discrimination of stream odors by fish and its relation to parent stream behavior. American Naturalist 85(823):223-238.

Hassler, T.J. 1987. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)- coho salmon. U.S. Fish and Wildlife Service Biological Report 82(11.70). U.S. Army Corps of Engineers, TR EL-82-4. 19 pp.

Hassler, T.J., C.M. Sullivan and G.R. Stern. 1991. Distribution of coho salmon in California. Annual Report of California Department of Fish and Game, Contract No. FG7292.

Hjort, R.C. and C.B. Schreck. 1982. Phenotypic differences among stocks of hatchery and wild coho salmon, Oncorhynchus kisutch, in Oregon, Washington, and California. Fisheries Bulletin, U.S. 80:105-119.

Hull, D., J. Ellinwood, C. Toole, and T. Flannigan. 1989. Humboldt Fish Action Council, final report project number C-1538, October 1986 through August 1988. Report to Harvey Reading, California Department of Fish and Game.

Jensen, P.T. and P.G. Swartzell. 1967. California salmon landings 1952 through 1965. California Department of Fish and Game, Fish Bulletin 135:43-57.

Johansen, R.R. 1975. San Lorenzo River (Santa Cruz County) winter steelhead and salmon fishery, 1971-72 and 1972-73 seasons. California Department of Fish and Game Anadromous Fisheries Branch Administration Report 75-6. 14 pp.

Johnson, M.L. 1964. San Lorenzo River system, Santa Cruz County. California Department of Fish and Game, Region 3 file report (unpublished). 8 pp.

-------------. 1971. San Lorenzo River, Santa Cruz County-creel census for the 1970-71 steelhead and salmon season. California Department of Fish and Game, Region 3 file report (unpublished). 12 pp.

Johnson, O.W., T.A. Flagg, D.J. Maynard, G.B. Milner, and F.W. Waknitz. 1991. Status review for lower Columbia River coho salmon. NMFS, NFC/Coastal Zone and Estuarine Studies Division, Seattle, Washington.

Jordon, D.S. and P.L. Jouy. 1881. Checklist of duplicates of fishes from the Pacific Coast of North America, distributed by the Smithsonian Institution in behalf of the United States National Museum, 1881. Proceedings of the United States National Museum 1881:1-18.

Jordon, D.S. and C.H. Gilbert. 1881. Notes on the fishes of the Pacific Coast of the United States. Proceedings of the United States National Museum 1881:29-70.

Lang, R.M. 1966. Stream survey, San Lorenzo River drainage. California Department of Fish and Game, Region 3 file report (unpublished). 5 pp.

---------. 1972. Stream survey, San Lorenzo River drainage. California Department of Fish and Game, Region 3 file report (unpublished). 6 pp.

Laufle, J.C., G.B Pauley, and M.F. Shepard. 1986. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)- coho salmon. U.S. Fish and Wildlife Service Biological Report 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp.

Leidy, R.A. 1983. Distribution of fishes in streams of the Walnut Creek basin, California. California Fish and Game 69:23-32.

----------. 1984. Distribution and ecology of stream fishes in the San Francisco Bay drainage. Hilgardia. 52:1-175.

Lockington, W.N. 1881. Report upon the edible fishes of the Pacific Coast, U.S.A. In: Report of the Commissioners of Fisheries of the State of California, for the year 1880, Sacramento, California.

Lufkin, A. (ed.). 1991. California's salmon and steelhead. The struggle to restore an imperiled resource. University of California Press, Berkeley.

Marston, D. 1992. June-July 1992 stream survey report of lower Scott Creek, Santa Cruz County, California Department of Fish and Game, Region 3 file report, (unpublished). 44 pp.

Martin, J.T. 1984. Social value of wild fish. Pg. 297-301, In J.M. Walton and D.B. Houston (ed). Proceedings of the Olympia Wild Fish Conference. Penninsula College, Fisheries Technology Program. Port Angeles, Washington.

Mason, J.C. 1966. Behavioral ecology of juvenile coho salmon (Oncorhynchus kisutch) in stream aquaria with particular reference to competition and aggressive behavior. Ph.D. Thesis, Oregon State Univ., Corvallis. 195 pp.

Mason, J.C. 1975. Seaward movement of juvenile fishes, including lunar periodicity in the movement of coho salmon (Oncorhynchus kisutch) fry. Journal Fisheries Research Board Canada. 32:2542-2547.

May, B. 1975. Electrophoretic variation in the genus Oncorhynchus: The methodology, genetic basis, and practical application to fisheries research and management. M.S. Thesis, Univ. of Washington, Seattle. 95 pp.

Mayr, E. 1963. Animal species and evolution. Belknap Press of Harvard University Press, Cambridge, Mass.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game Bulletin 157. 249 pp.

Monterey Bay Salmon and Trout Project. 1993. Memo to ESA Administrative Record for Scott and Waddell Creek's coho salmon re: Big Creek Hatchery annual production and stocking reports to California Department of Fish and Game for 1977-1993 (unpublished). Monterey Bay Salmon and Trout Project, Davenport, California. 48 pp.

Moyle, P.B., J.E. Williams and E.D. Wikramanayhake. 1988. Fish species of special concern of California. Final report to California Department of Fish and Game, contract No. 7337. 222 pp.

Murphy, G.I. and L. Shapovalov. 1952. A preliminary analysis of northern California salmon and steelhead runs. California Fish and Game 37:497-507.

Nehlsen, W., J.E. Williams and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho and Washington. Fisheries 16:4-21.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583-590.

Nelson, J. 1993. South central coastal stream coho salmon and steelhead trout population inventory and habitat assessment. California Department of Fish and Game, annual performance report F-51-R-5. 52 pp.

Nielsen, J.L. 1994, in press. Invasive cohorts: impacts of hatchery reared coho salmon on the trophic, developmental, and genetic ecology of wild stocks. USDA, U.S. Forest Service, Pacific Southwest Research Station, Albany, California. 58 pp.

Nielsen, J.L., C. Gan, and W.K. Thomas. 1994, in press. Differences in genetic diversity for mtDNA between hatchery and wild populations of Oncorhynchus. USDA, U.S. Forest Service, Pacific Southwest Research Station, Albany, California, and Department of Molecular and Cell Biology, Univ. California, Berkley, California. 29 pp.

Olin, P.G. 1984. Genetic variability in hatchery and wild populations of coho salmon, Oncorhynchus kisutch, in Oregon. M.S. Thesis, Univ. California Davis, California. 73 pp.

Pacific Fisheries Management Council. 1993. Review of 1992 ocean salmon fisheries. Pacific Fisheries Management Council, Portland, Oregon.

Painter, R.E., L.H. Wixom, and S.N. Taylor. 1977. An evaluation of fish populations and fisheries in the post-Oroville project, Feather River. California Department of Fish and Game, report submitted to the Department of Water Resources, Sacramento, California.

Pintler, H.E. 1956. The results of a fish population sampling program on the San Lorenzo River, Santa Cruz County, California. California Department of Fish and Game Inland Fisheries Administrative Report 56-26. 19 pp.

Pratschner, G.A. 1978. The relative resistance of six transferrin phenotypes of coho salmon (Oncorhynchus kisutch) to cytophagosis, furunculosis, and vibriosis. M.S. Thesis, Univ. Washington, Seattle. 71 pp.

Quinn, T.P. and R.F. Tallman. 1987. Seasonal environmental predictability and homing in riverine fishes. Environmental Biology Fisheries 18(2):155-159.

Reavis, R. 1985. Ocean Ranching in California: A report submitted to the joint committee on fisheries and aquaculture; the assembly committee on water, parks and wildlife; and the senate committee on natural resources and wildlife. California Department of Fish and Game, Anadromous Fisheries Division, Sacramento, California. (unpublished data). Submitted December 21, 1993 to ESA Administrative Record for Scott and Waddell Creeks coho salmon.

Reisenbichler, R.R. and S.R. Phelps. 1987. Genetic variation in chinook, Oncorhynchus tshawytscha, and O. kisutch, salmon from the north coast of Washington. Fisheries Bulletin, U.S. 85(4):681-701.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pp. 19-160, In R.C. Simon and P.S. Larkin (ed). The stock concept in Pacific salmon. H.R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver.

Salo, E. and W.H. Bayliff. 1958. Artificial and natural production of silver salmon, Oncorhynchus kisutch, at Minter Creek, Washington. Washington Department Research Bulletin 4:1-76.

San Lorenzo River Watershed Management Plan. 1979. Pp. 103-169 In G.H. Stauffer (ed), San Lorenzo River Watershed Management Plan. Santa Cruz County Planning Department, and California Department of Fish and Game, Protected Waterways Program. Santa Cruz, California. 240 pp.

Schlichting, D. 1974. Annual report, Feather River salmon and steelhead hatchery, 1970-1971. California Department of

Fish and Game, Anadromous Fisheries Board Administrative report 74-11.

Scott, D. 1993. Memo to ESA Administrative Record for Waddell Creek coho salmon re: Electrophoretic data on Waddell Creek coho salmon (unpublished). Memo dated December 12, 1993, 1 p. and enclosures. Department of Biology, Cabrillo College, Aptos, California.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board Canada Bulletin 184. 966 pp.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game Fish Bulletin No. 98. 375 pp.

Slatkin, M. 1981. Estimating levels of gene flow in natural populations. Genetics 99:323-335.

----------. 1985. Rare alleles as indicators of gene flow. Evolution 39:53-65.

Smith, J.J. 1987. Aquatic habitat and fish utilization of Pescadero, San Gregorio, Waddell and Pomponio Creek estuary/lagoon systems. Report to California Department Parks and Recreation Interagency Agreement 4-823-6004. 35 pp.

----------. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell, and Pomponio Creek estuary/lagoon systems, 1985-1989. Department of Biological Sciences, San Jose State Univ., San Jose, California. Interagency agreement 84-04-324 with California Department of Parks and Recreation. 97 pp.

----------. 1992. Distribution and abundance of juvenile coho salmon and steelhead in Waddell, Scott, and Gazos Creeks in 1992. Department of Biological Sciences, San Jose State Univ., San Jose, California. (unpublished) 13 pp.

----------. 1993. Summary of trapping results on Waddell Creek for 1992-1993. Department of Biological Sciences, San Jose State Univ., San Jose, California. (unpublished) 16 pp.

Snider, W.M. 1985. Instream flow requirements of anadromous salmonids, Brush Creek, Mendocino County, California.

California Department of Fish and Game, Environmental Services Branch, Stream Evaluation Report 85-1.

------------. 1989. Instream flow requirements of anadromous salmonids, Scott Creek and Waddell Creek, Santa Cruz County, California. California Department of Fish and Game, Environmental Services Branch, Stream Evaluation Report F-51-R-1.

Snyder, J.O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California, Fish Bulletin No. 34.

Solazzi, M.F. 1986. Electrophoretic stock characterization of coho salmon populations in Oregon and Washington, and coastal chinook salmon populations in Oregon. Oregon Department of Fish and Wildlife Information report 86-5:1-16.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. U.S. Department of Energy, Bonneville Power Administration, Technical Report 90-1.

Streig, D. 1991. History of fish cultural activities in Santa Cruz County with special reference to Scott and Waddell Creeks. Monterey Bay Salmon and Trout Project, Davenport, California (unpublished). 9 pp.

----------. 1993. The Monterey Bay salmon and trout project: project backgroud and description. Monterey Bay Salmon and Trout Project, Davenport, California (unpublished). 24 pp.

Suzumoto, B.K., C.B. Schreck, and J.D. McIntyre. 1977. Relative resistance of three transferrin genotypes of coho salmon (Oncorhynchus kisutch) and their hematological responses to bacterial kidney disease. Journal Fisheries Research Board Canada 34(1):1-8.

Taft, A.C. 1937. Marked silver salmon from Waddell Creek caught near Fort Bragg. California Fish and Game 23:117-178.

Thompson, G.G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS F/NWC-198. 78 pp.

Utter, F.M., W.E. Ames, and H.O. Hodgins. 1970. Transferrin polymorphism in coho salmon (Oncorhynchus kisutch). Journal Fisheries Research Board Canada 27(12):2371-2373.

Utter, F.M., D. Campton, S. Grant, G. Milner, J. Seeb, and L. Wishard. 1980. Population structures of indigenous salmonid species of the Pacific Northwest: I. A within and between species examination of natural populations based on genetic variation of proteins. Pp. 285-304 In W.J. McNeil and D.C. Himsworth (ed). Proceedings of the symposium on salmonid ecosystems of the North Pacific, May 1978. Otter Crest, Oregon. Sea Grant College Program, Oregon State Univ., Corvallis.

Utter, F.M., H.O. Hodgins, F.W. Alledorf, A.G. Johnson, and J.L. Mighell. 1973. Biochemical variation in Pacific salmon and rainbow trout: their inheritance and application in population studies. Pp. 329-339, In J.H. Schroder (ed). Genetics and mutagenesis of fish. Springer-Verlag, Berlin.

Waples, R.S. 1991. Definition of "species" under the Endangered Species Act: Application to Pacific salmon. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS, F/NWC-194. 29 pp.

-----------. 1990a. Conservation genetics of Pacific salmon. II. Effective population size and the rate of loss of genetic variability. Journal of Heredity 81:267-276.

-----------. 1990b. Conservation genetics of Pacific salmon. III. Estimating effective population size. Journal of Heredity 81:277-289.

Waples, R.S. and D.J. Teel. 1990. Conservation genetics of Pacific salmon. I. Temporal changes of allele frequency. Conservation Biology 4:144-156.

Wehrhahn, C.F. and R. Powell. 1987. Electrophoretic variation, regional differences, and gene flow in the coho salmon of southern British Columbia. Canadian Journal Fisheries Aquatic Sciences 44:822-831.

Winter, G.W. 1978. Resistance of coho salmon *Oncorhynchus kisutch* and steelhead trout *Salmo gairdneri* stocks and transferrin genotypes to bacterial kidney disease and vibriosis. M.S. Thesis, Oregon State Univ., Corvallis. 29 pp.

Wright, S.G. 1968. Origin and migration of Washington's chinook and coho salmon. Washington Department of Fisheries. Information Booklet 1. 25 pp.

PERSONAL COMMUNICATIONS

Anderson, K. California Department of Fish and Game. Monterey, California.

Cox, B. California Department of Fish and Game. Sebastopol, California.

Cox, W. California Department of Fish and Game. Rancho Cordova, California.

Hope, D. Santa Cruz County Planning Department, Santa Cruz, California.

Nelson, J. California Department of Fish and Game. Monterey, California.

Smith, J. Assistant Professor, Department of Biology, California State University, San Jose, California.

Streig, D. Monterey Bay Salmon and Trout Project, Davenport, California.